THE JOURNAL OF INDUSTRIAL ENGINEERING

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Vol. V, No. 5 **September, 1954**

Official Publication of the American Institute of Industrial Engineers, Inc.

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THE JOURNAL OF INDUSTRIAL ENGINEERING

VOL. V, NO. 5 September, 1954

Published Bi-Monthly By

THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS, INC.

Editorial & Publication Offices

A. French Building

225 North Avenue, N.W.

Atlanta, Georgia

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PRESIDENT'S MESSAGE

D. G. Malcolm

Since writing in the last issue of the Journal and suggesting that we give serious thought to the development of an adequate definition of the long-run objectives and problem-solving area of the Industrial Engineering profession, several have written and asked to have a definition. So in the interests of starting the ball rolling in such an introspective direction, I'll offer a few thoughts that have managed to become planted in my mind over the past few years.

The Industrial Engineer is essentially a problem solver, the problem to be solved is generally one involving, in some manner, the design of systems for people, machines and facilities which have been so organized together in the attempt to attain a defined objective. In general the system designed by the engineer should enable adequate prediction of cost and performance and provide satisfaction to the several parties to the system.

The job of the Industrial Engineer is a dynamic one, for, the systems involved function in a climate of constant change —where the "defined objectives" continually reflect the striving for maximum individual freedom so characteristic of our American way of life. Thus, it might be more appropriately written above that the Industrial Engineer is engaged in the design of "dynamic systems." This will indicate more adequately the human factors involved in the Industrial Engineer's work and indicates the need for great flexibility in the systems designed.

Our most successful managements of today are those that have correctly seen the payoff of an approach involving good Industrial Engineering. It seems unlikely to me that the Industrial Engineer will change or want to have changed his functional staff relationship to such management. What **will** change, and which is of more real importance to us than definitions, will be the breadth of the problems entrusted to the engineer and the types of techniques he will need to bring to bear in this job of design.

(Continued on Page 6)

OPERATIONS RESEARCH—
Widening the Horizon of Industrial Engineering?

By D. G. Malcolm [1]

I should like to set the stage for this discussion by citing a couple of quotations.

First, a quotation from an article [2] appearing in *Factory Management & Maintenance* (1) ". . . operations research is nothing but an extension of the best industrial engineering practice to include more advanced mathematical techniques," and later in the same article, "All in all, it's really a sharper kind of industrial engineering."

Second, from an article in *Scientific Monthly*, I would quote the following concluding remarks of Dean R. H. Roy (2): "Despite its history of controversy and the narrowness of its approach, organizations have profited from industrial engineering. It is fair to hope that even greater gains will come from the imaginative and resourceful teams of operations research."

Many other articles could have been quoted, however, the above will serve to introduce what can be taken as a challenge to the Industrial Engineer.[3] Perhaps the most significant result of such statements is how the industrial engineer is reacting to this challenge, if it so be. A whole gamut of reactions is evidenced ranging from complete acceptance to complete denial or rejection. The following statements are at least representative of the reactions of Industrial Engineers to this relatively new field, born in the military and now making significant strides in industrial applications.

1. A keen interest to study and cooperate with the field of operations research, assimilation of the name, absorption and adoption of the practical tools.
2. Rejection of the techniques as not practicable in given situations. When the system needs these techniques they will and/or would have been applied whether or not there was such a discipline as Operations Research.
3. Dispute the validity of the statement (here there are two opposite views):
   (a) Industrial Engineering is already doing everything indicated as being Operations Research and is therefore no less "sharp."
   (b) Industrial Engineering as a profession is nowhere near Operations Research in concept and therefore should not even be compared.

This is not a complete or precisely worded list of the reactions, but it will suffice to give a general idea of the kinds of attitudes observed. I am certain that after each Industrial Engineer has had sufficient time to study various other articles in the literature (3, 4, 5) and their bibliography (3), he will find himself leaning to some combination of the above statements. The distribution of the responses of all engineers after such study may in essence define what operations research is as far as engineering is concerned. Perhaps, and this is probably a more important result of such study, Industrial Engineering may thus be provided with a yardstick for determining what it thinks it is.

Defining a branch of science or a professional field is not an easy task (if possible)—a fact of which I am sure you are well aware if you have ever attempted to define Industrial Engineering, or engineering, for that matter. If you are interested in definitions, I have included a section on that later on in the article. At this point, however, I think it is sufficient to say that our pragmatic society generally demands descriptive or operational definitions in order to understand and accept the ideas proffered. In that vein, let us take a look at a few of the techniques that have been used and are being further developed by operations researchers.

Gaming

Gaming [4] refers to the physical manipulation of a model of a system which is not a complete mathematical one.[5] In general, gaming may be viewed as a complete paper trial of a proposed system for the purpose of discovering the effect of introducing change, ironing out bugs in a new system **before** making the change, and as a means for training people in the new system. One of the most important goals of operations research is this building of a conceptual model that includes all the pertinent known variables affecting the outcome.

Gaming should definitely be used to test systems proposed by application of Programming techniques and queueing theory which will be discussed in subsequent sections. Examples of gaming are to be found in both military and in industry.

The field army operates under a set of procedures and guides which are referred to as "doctrine." The actual effect of new weapons upon the overall system is impossible to quantify by present means. So a simulated paper operation or "game" is played to determine the probable effect of the weapon in "use." Playing of a sufficient number of games allows statements to be made regarding doctrinal changes that should be made in order to utilize the weapon most effectively. A theory regarding number of games to be played, etc., will gradually develop.

The application of this approach has been made in many industries by engineers. An industrial example is to be found in the design of a railroad classification yard (6) where a paper run of a drastically new concept in physical yard requirements and procedures was made, thus providing a test of the system before installation. However, gaming becomes more necessary as more complex systems are developed. In fact, it has been estimated that at least one half the cost in developing a radically different new system should be spent in gaming. The training and selling aspects will be increasingly more important, and are essential to the smooth introduction and success of a new system.

Programming

Systems planning may be performed by techniques known as linear-programming, a field which itself is expanding in mathematical concept and content. Some of the leaders in the development of these techniques have suggested (7) that the name "activity analysis" is a more accurate title since it includes the newer non-linear programming and dynamic programming.

These methods were developed in the main in the field of economics in order to provide an efficient basis for substitution, or allocation of resources. Other programming techniques involve use of electronic computers, such as placing purchasing and inventory records on these electronic devices (8).

In industrial application the objective of such analysis might be to maximize the profit or minimize the cost of a system that can be described mathematically and constrained by a series of linear inequalities. The technique is promising for use in production planning, but will require considerable development and refinement before becoming an acceptable technique. Perhaps an oversimplified example will indicate the type of analysis involved.

Suppose a bank of three machines performing Operation 1 in a sequence feeds a second bank of 5 machines which are performing Operation 2. Perhaps these have become located somewhat haphazardly over a period of time. It is your job to set up a flow pattern that will minimize handling costs, and possibly later use the results to determine whether a relayout would provide an economic payoff.

---

[1] Staff Member, the Operations Research Office, the Johns Hopkins University, Chevy Chase, Maryland.

[2] Numbers in parentheses refer to references at the end of this article.

[3] Since the industrial engineer is a part of the more all-inclusive class, engineer, these remarks have some application to the profession of engineering in general.

[4] Not to be confused with the Theory of Games, which is a technique of applied mathematics for determining optimum strategies in situations where several people can influence the outcome by decisions made.

[5] When sufficiently precise statements about probabilities can be made and a mathematical description of the system can be made, Monte Carlo methods may be used.

Let us suppose further that you have collected two arrays of facts by work sampling and time study techniques. Figure 1 gives the distribution of output by the bank of machine on Operation 1 and Operation 2. Figure 2 indicates the time costs which we will assume are directly proportional to the total material handling costs. The units are in minutes.

Operation 1	Operation 2—Mach. No. 1	2	3	4	5	Totals
Machine 1	x_{11}	x_{12}				1
Machine 2	x_{21}					5
Machine 3						7
Totals	3	3	3	2	2	13

Figure 1—Flow Matrix

Operation 1	Operation 2—Mach. No. 1	2	3	4	5
Machine 1	8	7	6	7	8
Machine 2	10	9	8	4	6
Machine 3	5	7	8	9	10

Figure 2—Cost Matrix
Minutes per Flow Path

Your problem is to fill in the squares in Figure 1 in such a way as to minimize the total time spent and of course, at the same time, being consistent with figures in the "totals" column. There are a lot of possibilities in arranging the flow from Operation 1 to Operation 2. Let's see how the linear programming analyzes this problem.

As you will agree, our objective is to find a minimum solution to the following expression:

$$8x_{11} + 7x_{12} + 6x_{13} + 7x_{14} + 8x_{15} + 10x_{21} + 9x_{22} + 8x_{23} + 4x_{24} + 6x_{25} + 5x_{31} + 7x_{32} + 8x_{33} + 9x_{34} + 10x_{35}$$

where the x's refer to the various squares of Figure 1.

This expression is subject to the following constraints (which can re-expressed in the form of linear inequalities):

$$\begin{aligned}
x_{11} + x_{12} + x_{13} + x_{14} + x_{15} &= 1\\
x_{21} + x_{22} + x_{23} + x_{24} + x_{25} &= 5\\
x_{31} + x_{32} + x_{33} + x_{34} + x_{35} &= 7\\
x_{11} + x_{21} + x_{31} &= 3\\
x_{12} + x_{22} + x_{32} &= 3\\
x_{13} + x_{23} + x_{33} &= 3\\
x_{14} + x_{24} + x_{34} &= 2\\
x_{15} + x_{25} + x_{35} &= 2
\end{aligned}$$

This becomes a problem in 15 dimensional space containing 15 unknowns and with only 8 equations to work with. Thus a sort of trial and error method must be employed to arrive at the proper values of x which minimizes the expression. One method, known as the simplex method,[6] requires approximately (m + n − 1) iterations in order to arrive at the minimum solution. In the example, 8 iterations, instead of 7 as indicated from substitution in (m + n − 1) were required. The solution to this problem is shown in Figure 3.

Operation 1	Operation 2—Mach. No. 1	2	3	4	5	Totals
Machine 1			1			1
Machine 2			1	2	2	5
Machine 3	3	3	1			7
Totals	3	3	3	2	2	13

Figure 3—Minimum Time Solution

Of course this example raises some serious questions regarding the practicality of the technique in a real situation involving variability of the time values and homogeneity with respect to time. However, at present, these are problems of model building and, of course, can only be solved by further research. One of the advantages of someone in the organization thinking in such terms is that only by this means can a system be precisely described and analyzed. This does offer the possibility of a method for analyzing and comparing alternate proposals for material handling systems. It may shed light on some of the hidden material handling costs or savings in individual incentive plans. It will provide a means of making the basis for a cost analysis.

Again, I want to stress the limitations in the above example. In some cases linear-programming will provide more than one solution and in other cases none. It is quite possible that the system may not be linear, that queues will form if the time estimates have variability. If the output-input is out of balance the problem is seriously complicated. A realistic evaluation of the data needed and **available** as well as qualified statistical help in setting up the programming are required before a successful application can be made.

Queueing Theory

The development of a queue, or waiting line, was mentioned above. Queueing theory was developed as a tool for analyzing the saturation of facilities such as ship repair facilities. It has been successfully used in analyzing the overloading of airport facilities, the serving of customers in a restaurant and to a host of industrial problems. It has been used as a diagnostic tool to evaluate the proper banks (in-process inventory) in job lot operations and to the design of optimum conveyor and material handling systems. It should also permit design of proper maintenance procedures. In this respect, other techniques under development are coming to be known as Failure Theory and Maintenance Theory. (11)

Suppose in our previous example we had machines occasionally requiring emergency maintenance. Incidentally, this is another limitation of that particular linear programming model which can be resolved if we know the probability and duration of the occurrence of the maintenance. Feller (9) derives a formula for predicting the probability of n machines being down and waiting service when there are m machines and one repairman available.

$$P_n = (m)_n \left(\frac{\lambda}{\mu}\right)^n P_o \quad \text{(Equation 1)}$$

where $(m)_n = m(m-1) \ldots (m-n+1)$

P_n = probability that there are n machines waiting maintenance

$\left(\frac{\lambda}{\mu}\right)$ = servicing factor—this may be thought of in this example[7] as the ratio of average servicing time to the average time between breakdowns.

Figure 4 indicates the solution when $(\lambda/\mu) = .1$, $m = 6$. Examination of this figure indicates that 77.5% of the time it may be expected that there will be no machines awaiting service. In regard to the repairman—he will spend this 77.5% in two categories—48.5% of the time he will be idle and 29% will spent in servicing one machine (with no machine waiting in line).

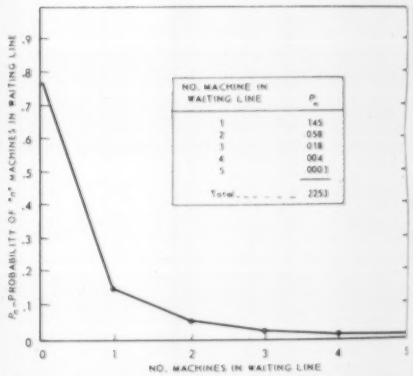

Figure 4—Probability of "n" machines awaiting service.

Now our "common sense" might have told us that if we had our total servicing time required for 6 machines **equal** to the breakdown interval, we would have no trouble with queues forming. However, notice in this case that our total servicing time is equal to only 0.6 of the breakdown interval and **still** we have a probability of .225 that a machine will have to wait in line for servicing. The

[6] This example adapted from Reference (7), Chapter XXIII, by G. B. Dantzig.

[7] $\frac{\lambda}{\mu}$ should actually be stated in probabilities. (9)

average length of this wait can be shown to be approximately .33 times the service time. This means that under these conditions you can expect to have machines idle waiting for service 22.5% of the time, and that each machine out of production will be down a period of time equal to one-third of the service time in addition to the service time. This is considerably different from what our common sense told us.

I'm certain any maintenance man will tell you that you can't plan so fine that service time will be equal to arrival interval and that therefore you need excess maintenance capacity. How much excess capacity do you need? Further analysis will permit you to minimize the combined cost of production losses and excess maintenance capacity. Work Sampling studies should agree with the amount of the resultant idle man time computed for P_0 which was found to be .485 in the above example.

Queueing theory will serve as a basis for adequate design of incentive plans. Note that an appropriate mathematical equation must be set up for each particular situation.

For an open-ended system, Morse has derived (5) an over-simplified equation [8] which describes the queueing problem:

$P_n = C^n (1 - C)$ (Equation 2)

P_n = probability of n units waiting for service

$C = (\bar{x}/a)$ servicing factor

x = average service time

a = average arrival interval

From this the expecting waiting time can be derived as:

$$E(t_w) = \frac{\bar{x}^2}{a - \bar{x}} \quad \text{(Equation 3)}$$

Figure 5 shows a plot of the $E(t_w)$ in percent of $\bar{x}$ various values of C. Note that when the servicing factor C=.5, the expected waiting time will equal $\bar{x}$, the servicing time. The assumption of random arrival is involved in the above, whereas our common sense tends to assume that each unit arrives at precisely regular intervals. The real situation normally has some probability statement that should be included so that the true solution will be somewhere in between our common sense and the above curve. Thus, the need for development of adequate mathematical statements (models) is essential.

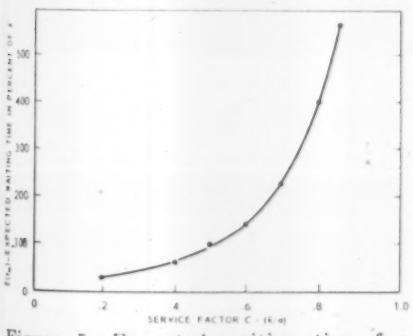

Figure 5—Expected waiting time for various servicing factors.

[8] This is offered for illustrative purposes only. The development by Feller is recommended.

Applicationg and development of queueing models for a host of industrial engineering problems is quite possible. Plant layout, material and production control, balancing of production lines can be quantitatively analyzed. Inventory banks at individual machines, maintenance help required, can certainly be minimized when sufficient time is spent in developing adequate models. Perhaps one of the most significant results of this theory is the insight it gives to the production process and the diagnostic value it possesses in analyzing and defining production bottlenecks. For example, in the maintenance problem it certainly offers convincing argument that certain idleness on the part of maintenance personnel is necessary in order to minimize production down time.

You will note that work measurement techniques will be required here, and that Work Sampling can be of real assistance. I believe that this is ample demonstration of the need to utilize current statistical tools in industry. This should indeed be a challenge to Industrial Engineering.

Other Quantitative Tools

The length of this paper precludes treatment of many other techniques which have been employed by operations research teams or are in the process of development. A listing of these is made for reference and items in the list of reference will provide greater details (3, 10, 11, 12, 13, 14 and 15).

Organization Theory
- a. Information Theory—Data Handling
- b. Feed-back Control
- c. Communication Theory

Search Theory
Failure Theory
Game Theory
Value Theory

All of these bear serious study by the Industrial Engineer.

Some Distinguished Characteristics of an Operations Research Activity

The examples used in this paper no doubt have given a distorted impression or definition of Operations Research. There are many examples where teams including social scientists and psychologists, have made excellent operational analyses (13, 14). At ORO, we have come to feel that operations research is characterized in the following manner:

1. Use of the mixed team, or interdisciplinary approach;
2. Use of the Scientific method along with adequate time allowed for the research and experimentation needed;
3. The overall or total system approach.

Thus it can be seen that Operations Research is essentially nothing new except that perhaps the existence of these three conditions simultaneously is somewhat unique organizationally in industry. It might be well to point out the impact of this uniqueness upon current organizational thinking.

The concept of an introspective staff function solely concerned with the duty of describing, analyzing and criticizing the enterprise as a whole, and on a continuous basis, may well become a most vital factor in the enterprise's success. This is becoming particularly true in an increasingly dynamic and more competitive world. In the future even more than at present good predictive ability will become the difference between success and failure. The manner in which a company organizes to provide this function therefore becomes a matter deserving considerable attention.

Operations Research has the distinction of being claimed by several other professional fields which all claim to be completely different. These include such fields as management consulting, industrial engineering, econometrics, systems engineering, mechanical engineering, general semantics, market research, applied statistics, and even cybernetics. This leads us to the consideration of the research nature of Operations Research.

When thought of as "research on operations," opsearch may be looked at as a cross-discipline research function which both applies and generalizes the formulated knowledge from various fields. Thus, it is quite natural that when this research function (OR) solves problems in any of the above professional areas—it looks like it really is a part of that professional area and may well be. The only really unique professional area that Operations Research can claim is the area of total system optimization, for it becomes apparent that all the other disciplines are making optimizations in only one phase of the business.

I am certain you can think of many instances where the Industrial Engineering was right, the sales forecasting was right, etc., and yet the whole endeavor failed or foundered. This is the kind of problem where research on operations is required and where a professional operations analyst may be efficient in defining and solving problems.

What Can Industrial Engineering Do?

I would suggest that Industrial Engineering avail itself of research on operations (or organizational structure) in much the same manner as in physical research related to other engineering functions. I submit that research on **how** an individual business system operates is equally as important as physical research on the products it makes.

This is the challenge to Industrial Engineering—to see that it is provided with the latest in diagnostic and predictive tools in order that optimum systems may be designed—to see that edu-

cational curricula are designed commensurate with the need for much greater emphasis on mathematical statistics, operational analysis, ethical systems, etc. (16)—to encourage individual engineers to continue in self-education and in personal growth, etc.

It should be pointed out that many forward looking engineering schools have recognized this challenge as is evidenced by references 17, 18 and 19 and many others not mentioned. However, if engineering is to maintain its position in the design of such human systems, the challenge will have to be met by more widespread development in engineering curricula. In the final analysis it becomes the responsibility of individual engineers to encourage and stimulate such growth and change in engineering curricula.

One of the biggest effects of the advent of Operations Research on the industrial scene is the new boost that is being given the Scientific Management cause. Perhaps some of the undue promotional efforts in the name of Operations Research can be forgiven, since it has been historically true that new names for the scientific management movement are needed periodically in order to provide the catharsis necessary to progress.

Definitions

Earlier it was indicated that there were other ways of defining a field. Three such methods of definition are offered:

1. **Definition by Objectives**—This generally amounts to a philosophical definition and quite often in effect states only the blueprint by which the leaders of the field have controlled their activities, and feel that the field should be striving towards. The practitioners in general will fall behind in their attempts to operate strictly in accordance with the objectives.

2. **Definition by Description of Practice**—A field is defined by the literature offered under that name, by seminars, by problems being worked on under that name, and by people who permit the title to be used as a fitting description of their professional activity. This may be termed a casuistic, or experimental, type of definition and has been the method used throughout the text of this paper.

3. **Definition by Comparison**—A field may be defined by comparing it with other fields, showing where it is different—where it is similar. This comparison may involve use of the above other two definitions also. In general, a feel for the boundary conditions of the field is thus afforded.

Earlier I stated that perhaps the unique professional field of Operations Research lay in the total optimization area. This is a goal rather than a reality, since quantitative models have not yet been made for total systems. Therefor, this may well be an "objectives" definition of Operations Research, for it is the belief of most engineers and scientists that order can be created out of chaos. To me, the following quotation of Korzybski sums up this frame of mind: (17)

> "The period of humanity's manhood, will, I doubt not, be a scientific period—a period that will witness the gradual extension of the scientific method to all the interests of mankind—a period in which man will discover the essential nature of man and establish, at length, the science and art of directing human energies and human capacities to the advancement of human wealth in accordance with the laws of human nature."

I believe that only through attention and effort toward such a goal will the dream of Korzybski become a reality. Those scientists currently only engaging in developing methodologies toward that end might well feel obliged at some future time to rename their field to something like "the Applied Philosophy of Science."

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PRESIDENT'S MESSAGE

(Continued from Page 2)

The implication of the last statement is important. Operationally, the Industrial Engineer is defined by what he does or can do for management. Therefore, the Industrial Engineer should recognize the kinds of problems he believes exist and which, when solved, will enhance his company's position internally or externally. He should then set about acquiring the tools with which to do the job. He also has a responsibility in suggesting needed items in the training and education of Industrial Engineers to the educational system.

What do you think of this definition? Perhaps it has raised more questions than it has answered, certainly a lot more can and should be said. At any rate, I've attempted to give the ball a little push and hope to have stimulated a little action on your part, either in the writing of your own definition, or—in a more "violent" method—by engaging in discussions with your colleagues concerning an adequate definition.

Turning to another subject, AIIE is pleased to announce the chartering of three new chapters since the convention in Louisville. My congratulations to the officers and members of the Ft. Wayne, Indiana, the Central Indiana, and the Toledo, Ohio Chapters of AIIE. May our associations be friendly and mutually beneficial! Organization meetings have been held in several other cities and by the time this message is printed and reaches you we should have two or three more active groups with charters to add to the present total of 36.

Another item I should like to bring to your attention is the fact that there are three regional conferences in various stages of planning. These are in addition to what appears will be our finest national conference which will be held in Saint Louis next May 12, 13th and 14th. These will certainly be "musts" on your calendar.

In closing let me urge you to bring problems of the profession to your local and national officers. The Executive Committee meets monthly in Columbus, Ohio, and is happy to consider all problems of the membership. Copies of the minutes of these meetings are sent to all chapter presidents and national committee chairmen. Let us know how we can be of service in improving our profession.

The Quality Bogeyman

By R. L. Geiger

Controller, American Aluminum Company

Many millions of dollars of production time are being wasted. They are being spent in a fruitless endeavor to satisfy the Bogeys of Quality Control. These Bogeys are:

1. "Ideal" Statistical Quality Control
2. "Ideal" Inspectors
3. The Specialist.

"IDEAL" STATISTICAL QUALITY CONTROL

No small amount of this waste is caused by a misunderstanding of the nature of Statistical Quality Control. The technique of Quality Control is honest and valid enough. It is a method of arriving at universal conclusions based on a random sample of the population concerned. It may easily be shown that in Inspection its proper use will save money and time. There are dozens of tales about "a $100,000 saving in inspection labor during 2½ years of operation under the Statistical Quality Control Plan."[1] Some experts aver that it has contributed to higher morale in some concerns.

"Quality Control has built higher morale in the shop because the man learns that the main interest of Quality Control is in helping him to improve, not in catching him in a mistake."[2] With it more can be learned about a mass-produced product than by old-fashioned, expensive, and inaccurate 100 percent inspection.

For some fifteen years after its discovery, the method was applied with consistent success to many problems in the telephone field, and was gradually extended to other spheres.

In World War Two, both the Armed Forces and Industry "discovered" this technique. Overnight, it became the darling of inspection departments. Its use spread with catastrophic violence, until today, everyone who makes equipment for the Armed Forces sometimes rues the day Dr. Shewart published his book! (Economic Control of Quality of Manufactured Product, 1931.) In the hands of unenlightened enthusiastics, its use has been misdirected. Now it is often one of the potent forces holding back production. Let me repeat, this is not a fault of the technique; it is its misapplication in the hands of specialists.

In their enthusiasm to spread the "gospel," these specialists overlooked an important principle. They passed over the word "Economic" on Dr. Shewhart's title page.

Many a man warned against this trend. "The credit we attach to the Quality Control program is attributable to the clear picture gained from Quality Control, which shows the quality level of a product and measures the progress being made in its improvement."[3] "Inspection then, does not add to the value of the product, since it performs no operation in it. Neither can inspection improve the quality of a product. Inspection, properly performed, will assure the customer of receiving products which meet the required standards of quality."[4]

Others ignored this advice. By failing to relate the technique to the over-riding necessity of producing *acceptable* work—and not necessarily perfect work—they caused a bottleneck in our production.

"IDEAL" INSPECTORS

Field inspectors are holding back perfectly good parts. They are rejecting material according to tables and statistics without having knowledge either of end use or of economically feasible levels of quality. In fact, it is safe to say that many inspectors feel that they must reject material or else their own jobs are in jeopardy. C. W. Kennedy noted that "Some individuals will never be adept at product inspection, anymore than some of us would ever break 100 par at golf, paint a picture, or preach a sermon, no matter how conscientiously we tried. Other inspectors simply will not take the care or assume the responsibility their jobs entail."[5]

In one experiment, inspectors were asked to pick out defective parts from a large batch of work. The pieces they passed were then secretly rerouted through the same inspectors. Almost the identical fraction was again rejected as bad—even though all had previously been accepted!

Visual quality is an ill-defined quality at best. Many components are rejected because the particular shade of color used in painting does not analyze spectrographically correct, although to the unaided eye there is no difference. Clear lacquer causes rejections for surface appearance; a wrinkle finish would be just as good and would cover minute imperfections.

I need only mention one warehouse stocked with a million dollars worth of material rejected by the military. Its rejection is for exceedingly minor visual defects that do not affect the working of the equipment whatsoever. The equipment is in daily commercial use.

According to Carl Day, "We found as a part of this defect program that our specifications in many instances were well beyond inspectors abilities to reproduce their readings even with the best aids available, optical or mechanical. We have given our employees yardsticks, when we should have given them microscopes."[6]

What seems most important to me is: does the part work, and will it last for a sufficiently long time?

A common practice is to write extremely close inspection specifications for field inspectors. The supervisor retains somewhat wider tolerances. In turn, he may be over-ruled by the design or engineering departments. Here the cynical design engineer tightens up the tolerances because he "knows" the shop will not keep within the real tolerances unless he did so. Thus needless delay is encountered by the unwillingness of the designer to trust the shop. By a similar line of reasoning the sub-Contractor is caused needless delay by the unwillingness of the prime contractor to trust him.

Safety of personnel is the prime consideration. This is especially true of aircraft components. But a long series of aircraft disasters is proof enough that insistance on outlandish quality nullifies the advantages that could be gained from proper control.

What actually happens? Suppose the flow of accepted work has not kept up with demand, in that case "higher authority" sets aside their rigid requirements and accepts quantities of sub-standard material. These are released on a batch basis.

Here lies a far greater danger to the safety of personnel than in having originally allowed for commercially necessary deviations. To release sub-standard material only qualitative standards can be set. These vary from batch to batch. They depend on the individual judgments of different inspectors. Thus we introduce an extremely dangerous variable.

A further effect of the large number of initial rejections is the enforced use of material longer than safety permits, because of inability to obtain spare parts from the manufacturer. He has enough to do to get production okayed, without worrying about spares.

Until you have gone through such an analysis as J. M. Juran outlined, "You have no idea how foggy the present division of responsibility is to the people who are directly concerned with product quality."[7]

[1] D. C. Peterson, A.M.A. Prod. Ser. No. 195 Quality Control-Organization and Administration, 1951, page 31.
[2] E. H. Robinson, Industrial Quality Control, May 1952, page 63.
[3] D. C. Peterson, op sit.
[4] Joseph Manuele, A.M.A. Prod. Ser. No. 185. "Quality Control—What it is and What it Does," 1949.
[5] C. W. Kennedy, A.M.A. Prod. Ser. No. 173. "Practical Applications of Quality Control Principles," 1947, page 30.
[6] Carl A. Day, A.M.A. Mfg. Ser. No. 206, "Quality Control: Tool for the Manufacturing Executive," page 20.
[7] Factory Management and Maintenance, Nov. 1952, "Six Steps to Inspection Management," page 114-117.

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PERFORMANCE RATING USING THE SAM FILMS

By R. O. Swalm

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One of the most widely used sets of films for training in rating proficiency are the SAM films. These films represent a very laudable effort on the part of the Society for the Advancement of Management. However, there appears to be a basic error in the method proposed in the SAM Film Rating manual for obtaining ratings for use in individual companies. This paper is presented in an effort to demonstrate that an error does exist, and to present a better method.

What is this error? It is the requirement that one's concept of normal pace be a function of the allowance used—in particular, that function which makes the standard time per piece **completely independent of the allowances used.** Stated another way, this function makes the required output per day for expected earnings independent of the allowances used. This means that if a company, through diligent effort, managed to reduce the allowance required for relaxation by introduction of air conditioning, as suggested by Dr. L. A. Bouha in the 1953 SAM-ASME Time and Motion Study Clinic—or by reducing the allowances needed for minor delays through better management — it would find that the standard time per piece, or the expected output for incentive rate, would not increase This is because the concept of normal proposed in the booklet "How to Use Performance Rating Films" would require that the concept of normal be revised to just that extent that the expected savings from the changes is eliminated.

Can this be true? It not only can, but is. This can be shown in either of two ways—either empirically, through the use of an example — or mathematically through the examination of the formulae which are used. Let us look at the empirical approach first.

Suppose that we are interested in determining the standard time for the operation "pack gaskets" as found in SAM Rating Film No. 2. Suppose that we agree that the pace exhibited in Scene 1 is the same as that exhibited by an operator in our shop; and we wish to determine the standard time for the operation.

According to the instructions in the booklet "How to Use Performance Rating Films" we find that we should:

1. Determine the allowance for the operation, taking into account "such factors as Personal Needs, Relaxation, and Minor Delays."
2. Determine the "expected attainment." This, "expressed in percentages, represents the amount above 'normal' which the average qualified operator, working at incentive pace, is expected to be able to achieve. The commonly used figure of 125% means the average operator is expected to be capable of producing up to 25% above the normal." (Parenthetically, we might question the words "up to" and "to be capable of" in the last sentence. Does this mean 125% is the maximum he can achieve? That is what the words say, although the intent would appear to mean that the average of a large group would achieve 25%—and that there would be individual earnings above or below that figure).
3. Enter the "Table of True Ratings" with these factors to determine the rating to be used.

Let us apply these instructions to a specific example. Suppose that in your plant the allowance used is 20% and the expected attainment is 110%. From the table, we find the "true rating" to be 116. Since the actual time for this operation is 0.272 minutes, the normal time for the operation will be 0.272 x 1.16, or 0.316 minutes; and the standard time will be 0.316 x 1.20, or 0.378 minutes.

Now let us assume that, through management effort of the type described above, your allowances are reduced to 10%. Now if you ask your time study men to rate the same film they should enter the Table of True Ratings with 10% allowance and 110% expected attainment. In this case, they will find the "true rating" to be 138%. This will yield a normal time of 0.272 x 1.28, or 0.348 minutes and a standard time of 0.382 minutes—which is the essentially same value as that obtained at 20% allowance. In fact, if the allowance were to drop to zero the results would remain unchanged —in this case the operator would be rated at 139% and the normal and standard times would both be 0.272 x 1.39 or 0.378 minutes.

We have thus demonstrated the proposition that, in at least one case, the concept of rating as set forth in the literature accompanying the SAM films yields a standard time that is independent of the allowance factor.

Can it be shown that this will be true in all cases? For the answer to this question we must turn to the mathematical approach. The formulae on which the values found in "How to Use Performance Rating Films" are based are those in the earlier SAM publication "Manual of Performance Rating." In this we find, on page 14, that, for any scene shown in the rating films, that the rating factor is given by

$$1.\quad \text{Rating Factor} = \frac{\text{Incentive Time per cycle} \times \text{Expected Attainment in \%}}{\text{Allowance Factor}} \Big/ \text{Actual Cycle Time}$$

where the incentive time per cycle is defined as "The allowed time for average of qualified incentive workers."

In order to convert from an observed average time to a normal time we use the formula

$$2.\quad \text{Actual Time per cycle} \times \text{Rating Factor} = \text{Normal Time per cycle.}$$

And to convert this to standard time the formula

$$3.\quad \text{Normal Time per cycle} \times \text{Allowance Factor} = \text{Standard Time per cycle.}$$

Combining 2 and 3 and substituting the value of rating factor yielded in 1, we obtain

$$\text{Standard Time/cycle} = \frac{\text{Actual Time per cycle} \times \text{Incentive Time per cycle} \times \text{Expected Attainment in \%} \times \text{Allowance Factor}}{\text{Allowance Factor} \times \text{Actual} = \text{Incentive Time per cycle} \times \text{Expected Attainment in \%}}$$

Obviously, this says that the standard time per cycle is independent of the allowance required—and therefore does not decrease when allowances decrease, nor increase when allowances increase.

Let us now look at the effect of this curious line of thinking on daily earnings. In an 8 hour day, we expect the operator to work $\frac{480}{\text{Allowance Factor}}$ minutes. During this time, he can produce

$$\frac{480 \text{ min.}}{\text{Allowance Factor}} \Big/ \frac{\text{Standard Time per piece}}{\text{Expected Attainment in \%}}$$

pieces, if he works at incentive pace during the time he is working. Since he will receive, in standard minutes, pay for this number of pieces time the standard time per piece, he will receive, in standard minutes,

$$\text{Standard Minutes per day} = \frac{480 \text{ Minutes}}{\text{Allowance Factor}} \times \text{Std Time per piece} \Big/ \frac{\text{Standard Time per Piece}}{\text{Expected Attainment in \%}}$$

or, simplifying

$$\text{Standard Minutes per day} = \frac{480 \text{ Min.} \times \text{Expected Attainment in \%}}{\text{Allowance Factor}}$$

This says that he can receive full incentive pay for the day only if the allowance factor is 1.00—or, in other words, he has no allowances. If he has any allowance time—and takes the time allowed —he cannot, by working at incentive pace the rest of the day, receive a full days incentive pay. The greater the allowance the further his pay from full incentive rate.

Stated another way, this says that an operator cannot receive full incentive pay for incentive work unless

a. His allowance is zero.
b. He works at faster than incentive pace while working.
c. He works at incentive pace but takes none of the time off which the allowance factor purports, for presumably good reasons, to give him.

Any of these alternatives lead inevitably to the conclusion that, either intentionally or not, the philosophy demanded by the use of the SAM manual can be stated as "Allowances are not necessary." But we are stuck with them. Let us, therefore, hide, in a series of fairly complex mathematical manipulations, a

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The Meaning of Operations Research

By Van Court Hare, Jr.

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(Delivered at the December 17, 1953, meeting of the East Tennessee Chapter of the American Institute of Industrial Engineers.)

When the Chinese Communists entered the Korean war in November, 1950, they used tactics which were dismaying and apparently unpredictable to UN troops. An Operations Research Consultant, S. A. Marshall, military analyst of the DETROIT NEWS and Army reserve colonel, nailed down these tactics by interviewing scores of men they had been used against.

From foxhole to foxhole he heard tales of strange oriental music the communists played before the erratic actions commenced. According to rumor the music was a form of psychological warfare the communists had invented. But Marshall, skeptical until he checked for himself, asked the men he interviewed to whistle what they remembered of the pre-attack music.

Through his methodical investigations, Marshall discovered the Chinese were using strange bugle calls to transmit their tactical signals—in place of the radio they did not have. In cooperation with Army associates, Marshall compiled a tactical song book, which tabulated bugle calls and the tactic which usually followed, enabling our troops to predict what the enemy was up to.

In this case, survey techniques were used to collect data and qualitative categories were formed in the instruction book as a solution to the problem.

When Seabrook Farms, Inc., a frozen vegetable producer in New Jersey, experienced excessive machine overloads at harvest time, a method was sought to improve the situation. C. W. Thornthwaite, an OR analyst, investigated the possibility of staggering crops at planting time to eliminate the hectic rush of a concentrated harvest.

He tried to devise some method of numerically tabulating the growth rate of crops day-by-day, including some correction for effects of weather extremes during the season. Peas, for example, grow from one point, then increase in size by nodes, or small steps like bamboo, which are easily counted. For two years, from January to summer harvest, Thornthwaite counted pea "growth units" each day and plotted them on a daily growth calendar. The maturity date for any planting date, he found, could be predicted from his calendar, and, if weather extremes intervened, suitable corrections could be made in terms of pea growth units. Growth of other crops, such as corn and beans, was rated in terms of equivalent pea growth units.

Finally, from this study of plant growth, described in rough "growth units," the machine scheduling problem was solved by efficient staggered planting methods.

C. C. Herrmann and John F. Magee of the A. D. Little Company in Boston recently investigated the sales program of a coffee distributing organization. The effects of promotional effort upon the size of dealer orders per month was the main point of interest in this study.

From past sales records and experiments the OR investigators found that (for this particular company) well-known probability distributions described the way in which orders were placed. Using their mathematical equations as a guide, Herrmann and Magee were able to design promotional experiments, describe the effect of promoting any fraction of the total dealer organization, and develop techniques for selecting the optimum set of dealers for promotion, if only part of the total group were pushed.

Refined mathematical techniques and a formal mathematical "model" were of major use in this operations research problem.

Persons who practice operations research—and this is a point worth making—have the habit of not restricting themselves to one type of problem, one type of data collection, or one set of analytical techniques. They like to study what seems important in their organizations at a given time, to collect data which seems relevant, regardless of its attributes, and to use whatever analytical techniques seem applicable to that problem. A look at articles in the *Journal of the Operations Research Society of America* will give you some idea of the diversity of present investigations.

If Operations Research is really a scientific discipline, then, what ties all these problems and techniques together?

OR Problems Have a Common Factor: Decision

The answer is that all of the problems we have discussed required a decision to be made, all of them required a method of inquiry which could evaluate alternatives considered for decision.

For example, the decisions implicit in the three OR examples given were:

A. Shall I promote large accounts or small accounts?
B. Shall I plant peas in January, or on May 1?
C. Shall I expect a frontal attack, or one from the flank?

The meaning of operations research can be found by asking pertinent questions about the decision-making process. But, before doing so, it will be worthwhile to note a historical trend in scientific interest—from simple to complex problems.

OR: A Method of Inquiry Aimed At Evaluating Decisions in Complex Situations

If you consider some problems in science, war, and industry, you will see that over the past fifty years practical problems have become more complicated; that the cost and difficulty of scientific investigations have increased; in short, that in the most interesting choice situations, making a decision, or reaching one, is not a simple problem.

A. Science

As a result, a type of secondary thinking has grown up regarding the methodology of research in natural sciences and in social sciences (research on research methods, so to speak) to aid in the decision as to which research procedure is best for a given problem. This is essentially operations research.

R. A. Fisher's agricultural experiments are an example of this trend. He found his work required a shift from the classical notion of an experiment, in which one variable was manipulated at a time, to a scheme in which many variables could be tested at once. The result was his factorial design of experimentation. In experimental physics, the problem of the interaction of instruments with the phenomena being measured raised the question of which measurement technique or alternative was best in certain cases. When the Census Bureau found the cost of conducting surveys and public opinion polls was increasing rapidly, its researchers placed new emphasis on selecting the most efficient research technique for a given study. In the field of electrical communication, when the introduction of the new electronic circuits using "feedback" required new and more complicated analytical techniques to be developed, complex decision making (in the circuits of computers and control devices) became a field of interest. Cybernetics, or generalized control theory, was the outcome of the latter development.

In science, then, analysis and decision-making have increased in complexity. Interrelated variables, feed-back effects (the problem solution or investigation affects the problem conditions), and the indivisibility of large area problems into simple ones have become the major worries of the research worker.

B. War

The complexity of military operations has produced a need for some means of

evaluating weapons, tactics, and strategies. The success of scientists in handling quantitative evaluations in their own fields (and in producing or innovating problem solutions) caused science to be drawn into military operations.

As early as the third century B.C., scientists researched for military evaluations. For example, Hieron, the King of Syracuse, appointed Archimedes to evaluate plans for the defense of that city against the Romans.

In World War I, Thomas Edison investigated the submarine menace using statistical calculations, and an Englishman by the name of Lanchester calculated possible air force strategies using differential equations.

In World War II, British scientists were drawn into the war effort, originally to aid in the conversion of the air defense network—which formerly used girls as plane spotters—to the new radar system which had been developed. The organization of the new operation was so successful that the scientists were drawn into other military positions; submarine warfare, the air force, the navy, civilian defense, and supply. The notion of having teams of operations research men attached to military commands was taken up by the U. S. Army, Navy, and Air Force, toward the end of WW II, and such teams were used extensively in Korea.

C. Industry

The complexity of modern business and industry has also produced the need for decision-making methods which are more and more efficient.

For example, Taylor began his "science of man's work" in the early 1900's. Gantt developed his scheduling charts at that time to aid in production decisions. The Gilbreths began evaluating job performance by quantitative methods a few years later.

During the thirties the number of staff specialists in industry increased. (One distinction to be noted is that most specialists worked alone then, on isolated problems, as Taylor and Gantt had done before.)

In the forties, the larger consulting firms, realizing that no one man could be a specialist in all management techniques, began to organize staff specialists into teams for a unified attack upon their clients' problems.

After WW II, many consulting firms and large corporations, such as GE, Atlantic Refining, Bell Labs, Curtis Publishing Co., Metropolitan Life, US Rubber and others, began to set up permanent **operations research teams**, in which scientists and business specialists—with an even broader background of experience in diverse fields—were given freedom to investigate problems of general interest, and to trouble-shoot in all parts of operating organizations. Industrial interest in operations research was, of course, spurred on by the success of military OR teams. The development of fast statistical and computational techniques, which resulted when scientists worked on problems in their own fields, also aided. But—as you have probably gathered—the advent of operations research teams in industry is also part of a trend of interest toward complex problems, which started many years ago.

Complex decision problems which are repetitive lead to the use of probabilistic decision making methods which are our next subject.

How Are Decisions Made?

Games of Chance were the origin f most modern theories of decision. For example, in 1796, Laplace, the French mathematician, summarized his ideas of probability in a series of public lectures, and, in one lecture entitled "Concerning Hope," stated the classical concepts of calculating how to make optimum decisions at games of chance (where events occur at random).

Modern thinkers, such as Wald, von Neumann, and Morganstern, have considered situations where overt competition is present, that is where outcomes of a game do not occur at random, but are affected by its players or contestants.

Since writings on decision theory are difficult to obtain and are often presented in mathematical symbolism, I should like to outline briefly some fundamental ideas on this subject in simplified terms.

A. What A Decision Involves

Three terms are often used in speaking of decisions: value, probability, and worth. You will see what these mean from the following example.

EXAMPLE — Classical Evaluation of Games of Chance. If you throw two dice, and the dice fall at random, the **probability** that the outcome 7 will occur is 6/36. Suppose that I agree to pay you $4 for $1 if you bet on 7 (and 7 actually occurs), and that you will pay me $1 every time you roll the dice and 7 does not occur. Then the **value** to you of the outcome 7, if you bet on 7, is the most you could win on 7, or $4; and the **worth** of outcome 7 is the product of its probability and value (your probable return on that outcome, not considering losses on other events), 4 x 6/36, or 24/36. Similarly, the value of all non-7 outcomes is $1, since you would lose $1 on non-7's, and the worth of outcomes other than 7 will also be negative in accordance with the probability distribution for dice games, as shown in Figure 1.

Thus, **value** has to do with **how much** you can win or lose when certain individual outcomes occur; **probability** with the number of times such favorable or unfavorable outcomes will occur in the long run (**how often or in what proportion** you will win or lose); **worth** with the **probable return or cost** of individual outcomes if you play the game for a long time.

The summation of the worths of all outcomes possible for a given alternative (say, "bet 7") is called the expected worth of that alternative, or simply its **expectation.** The expectations of "bet on 7" and "bet on non-7" in the game proposed are minus 6/36 and plus 6/36 respectively, meaning that if you played this game with me you could expect to lose roughly 17c for every dollar you put up betting on 7, and I would expect to win 17c for each dollar you bet on 7, presuming we played the game for an extended period of time.

B. Reaching a decision

For games of chance, the simplest criterion for making a decision—that is for making a selection of alternatives—is to pick that alternative which has the greatest expectation when compared to all other alternatives possible in the game.

More complicated criteria must be used for complex problems; for example at poker or in business where events do not necessarily occur at random, or in situations when you are short of captal, when your opponent begins to guess how you will bet, when he can change the odds himself, etc. The concepts of min-max, max-min, and other decision rules apply in problems of the latter type, and the following additional problems are important.

C. Some decision-making difficulties

1. Determination of the value of an outcome and the probability of its occurence may be very difficult or impossible in practical problems. When the rules of the game we play are not well-defined, we may not be aware of all the implacations of a given decision, its possible outcomes, all the alternatives we should consider, etc. The outcomes may not be repetitive, so we cannot estimate the probability of their occurrence easily.

2. In all but the most trivial cases, the problem of conflict is usually present in decision-making. Conflict, which confuses the values we should like to assign to outcomes under consideration, and implies dependent rather than independent

IF the sum rolled is → / then Worth of	Possible Outcomes: Sum of Two Dice Thrown at Random											
	2	3	4	5	6	7	8	9	10	11	12	E(W)
Bet on 7 →	-1/36	-2/36	-3/36	-4/36	-5/36	+24/36	-5/36	-4/36	-3/36	-2/36	-1/36	-6/36
Bet non-7 →	+1/36	+2/36	+3/36	+4/36	+5/36	-24/36	+5/36	+4/36	+3/36	+2/36	+1/36	+6/36

WORTH = VALUE x PROBABILITY

Figure 1—Worth of outcomes at a proposed dice game.

probability calculations may be of two kinds: conflict between our goals or standards of value (internal conflict), or conflict produced by competitors (the enemy, the environment, etc.). The latter is external conflict.

a. **Conflict of goals,** or sets of values, occurs, for example, if one of our goals is to obtain the maximum profit from a given activity, and at the same time another goal is, say, to observe certain moral scruples against that activity. An extreme case: the possibility of operating a profitable numbers racket vs. moral scruples against it. We often resolve internal conflict by the use of a more general goal or standard which includes the conflicting goals as sub-elements.

b. **Conflict from competition or nature** is more obvious. In this case we develop counter-strategy, consider shifting our goals to fit new environmental conditions, or develop new tactics: we may manipulate our competitors by force, propaganda, etc., or devise machines or techniques to change the environmental situation to our advantage. Problems of research implementation come here.

D. Decision-Making in an Organization

Figure 2 illustrates some components of decision in an organization, one of the most complex situations we can consider:

If you look at Figure 2, you will see that a problem in any part of an organization has effects in all parts of that organization, and also has effects in the environment in which the organization exists. Statistically, this is a multivariate problem. Customers, competitors, operators, and management are all part of what may be called a closed loop. The policy maker hopes to optimize the effectiveness of his organization, with respect to some goal, by choosing one or a combination of **n** policies (the numbered boxes in the figure above) which specify the routine operation of his system. In doing so he must consider in one form or another—and this is the point of our discussion of games of chance—the value of his decision's outcomes (positive or negative and of what magnitude of importance) and the probability that such favorable or unfavorable outcomes will occur. He must, unfortunately, face all the problems of decision making we noted: conflicts, poorly defined values and goals, lack of rules at his game and the like.

Operations Research could be of use to the executive in his policy making, then, if it concerned itself with value, worth, probability, and expectation, and developed techniques to overcome decision-making problems. Because of this motivation **the most obvious characteristic of modern operations research is the formulation of its problems in the decision-making terms we have discussed.** Such decision-making concepts are the meaningful core of operations research,

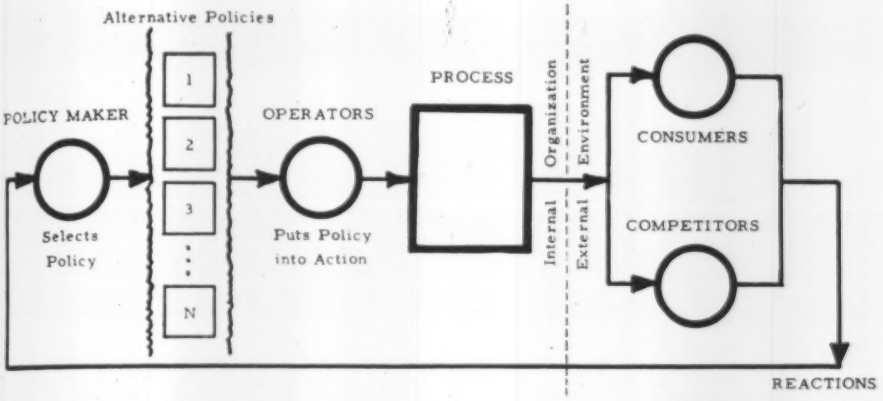

Figure 2—Some components of decision in an organization.

and the basis of its usefulness to the executive.

During WW II, the decision as to how large a bomber group to deploy against the enemy's artillery hinged on a certain intangible value—the value of a man's life. Certain Allied losses were expected—certain damage of enemy forces and installations was also expected—for each plane dispatched. What was the proper balance? No executive wished to hazard a guess on the value of a man's life. Most said "very high," but no one knew. Operations research teams were asked to resolve the dilemma by determining how much was actually spent to place and maintain a man in battle. Computations indicated that the apparent value was almost equivalent for all forces, and this value, in combination with the probabilities of damage and loss, led to decisions to increase the size of formations, saving both life and equipment for equivalent damage to the enemy. The value of one man's life in battle was said to be about $200,000. Even in this extreme case, logical decision-making contained the key concepts of value, probability, and certain rules for determining the expected worth of alternatives.

The Decision Model

One specific technique — the decision model—is of general interest to us here, because it has been used to combine decision theory with practical applications.

A model, as the name would imply, is a representation of a problem under consideration — in mathematical, symbolic, classificational, or other form—which is a miniature or simplified version of the actual operation or process under study. The simplification occurs in a certain way, however. In most cases, the model will represent the structure or relationship of variables in the problem—like the relationship of rooms in a house we propose to build or redesign—and is used to test the effect of manipulations we might perform to improve the process or situation, understand it better, and evaluate decision variables. One tries to avoid making decision models simple by leaving important variables out of the problem—like forgetting to have a bathroom in a house model—a fault which often occurs in unfamiliar situations unless we are careful. The "art" of operations research lies in knowing what to put in and what to leave out of the decision models we construct. So far, past experience, imagination, and hard work are the only guides one can use in this selection.

Industrial Engineers use models in their own work—this idea is nothing new. The interesting point to note, however, is that we can use decision models in situations frequently overlooked.

For example, in the Korean bugle call problem we discussed, the song "instruction" book was a classificational model or outline of possible communist action; in the Seabrook Farms example, the study of "pea growth units" served as a model for growth of all crops on the farm; in the Herrmann and Magee study, formal equations were models of the market situation. For certain common operations problems, well defined models have been developed: Life-and-Death Models (for replacement of elements in a system, repair, maintenance, etc.), Input-Output Models (for rate of input to improve output), Queueing Models (for rate of flow, congestion, waiting, etc.), Cybernetics Models (for control of a process through communication), Game Models (for choice in competitive situations), and Search Models (for the location of specified objects or events).

The above models are statistical or probabilistic ones, which have proved useful in complex situations. The classical type of model, which does not use the concepts of probability, is called a deterministic or mechanical model; although it seems to be of less use in handling crude experimental data than the probabilistic model, it is a very useful tool in decision-making, and thus deterministic models, such as graphs, tabulations, electrical and mechanical analogues, algebraic equations, and simple arithmetic should not be overlooked or considered too trivial for application.

To conclude our discussion of the meaning of operations research, I should like to present a check list of some of the steps normally followed by an operations researcher in his investigations.

The critical steps are at the beginning and the end of the research procedure—in the formulation of the problem and the implementation of its solution.

(Continued on Page 13)

Why Timestudy Standards Cost Too Much

By Martin R. Doring

Supervisor of Standards, Whitney-Blake Company, New Haven, Conn.

All of us are faced with inflation and rising costs. You and I can't do much more than talk about many phases of the problems these have created. That is very frustrating—to use a ten dollar word.

We, in timestudy, are extremely cost conscious. We are always looking for new ways to reduce costs. That is our job. But have you ever noticed that we seem always to be analyzing other people's jobs? What have we done to reduce the costs of our own work? We all take a great deal of pride in pointing out labor savings that we have brought about. Certainly we must continue to do this. But many of us cannot say the same about our own work. Have we made the same improvements in setting time standards as we have in our manufacturing costs? I don't think so, and therefore we must sit down and analyze our own methods.

The cost of setting time standards is far too great in most timestudy departments. Normally this is not due to lack of skill and intelligence on our part. Rather, it is because we fail to use the better methods available to us. We have many new tools at our disposal that we can use to reduce the costs of setting time standards. Using these tools may well be compared to an engine lathe in the tool room with an automatic screw machine. Obviously the set up time on the screw machine is much greater than the engine lathe. After the set up has been completed on the screw machine the per piece cost is much lower than pieces produced on the engine lathe. The same is also true of our Standard Data. If we are willing to take the initial time and expense to set our data up properly in the first place we can set standards in a fraction of the time it would normally take. Since we recognize this principle in our factory operations why don't we in our own work?

Can you set a standard in less than one minute that is within five per cent of accuracy and is consistent with others throughout the range of your product? Can you do this with men who are not highly skilled? Could you let your secretary set standards? Such simplifications are not only possible but also are entirely practical in many instances. In our plant my secretary sets more time standards than any one of the timestudy men. This is possible on the operations where we have reduced standard setting to reading tables. This also frees the timestudy men for development work and reduces the amount of time they spend on routine work.

Now you may say that this might work in some plants that have large runs but it won't work in a job shop. If yours is a job shop you have all the more reason for doing it. Your main problem is to get coverage by standards at a cost you can afford. This problem is quite common. Unfortunately, the solution isn't.

In one plant where I worked, we had all the headaches of measuring job lots. We decided that if we were to get any coverage at all we had to do something to solve our problem. Our solution came through the use of multi-variable charts. Since I was familiar with this method in general, I started to work out a solution. Before long, I ran into a blind alley. I needed additional help, as I had worked out a partial set of standards but there were still some elements I had not been able to incorporate in my charts. I found my answer in Phil Carroll's "How To Chart Timestudy Data."

This book can be seen in most Timestudy Depts. In my experiences I have noticed copies of this book in many plants. But, surprisingly enough, all have appeared to be practically as good as new. This is an indication that we realize the potential value of the book but somehow just fail to set aside enough time to read it.

The surprising thing to me about this unique method of charting is that it is relatively unheard of. Also, I thought that it was a new approach until I read of Phil Carroll's experiences with it. One of his examples dates back to July 1924. So you see this is not a new approach. Instead, it is a practice or method that is not used enough.

As an example, I was called into one plant to check their Standard Data for making wooden shipping boxes in their carpenter shop. The boxes they made covered a complete range in size, quantity and type of construction. The smallest were about 12 inches long, 8 inches wide and 6 inches deep. The largest were about fourteen feet long, 6 feet wide and 8 feet deep. The lot sizes could vary from one to 50 boxes of the same size. Construction was determined by the type of box and whether the shipment was to be domestic or foreign.

In reviewing the standard data their timestudy engineers had developed, it appeared to be a very thorough and well defined piece of work. Their analysis was very complete. It was broken down into handling, sawing and nailing for the several parts of the boxes being made such as top, bottom, sides, ends and cleats. Up to this point their standard data was a fine job. But it did not go far enough. It wasn't consolidated. It took between one and two hours for an experienced timestudy engineer to set one standard. The reason for this was that all of the following computations were necessary.

1. Volume of box in cubic feet.
2. Area of cover in square feet.
3. Area of side in square feet.
4. Area of end in square feet.
5. Depth of end in inches.
6. Depth of end times two in inches.
7. Width of end in inches.
8. Width of end times two in inches.
9. Length of bottom in inches.
10. Linear inches around bottom (twice the length plus twice the width of bottom.)
11. Total number of board feet in the box.
12. Size of cleats for foreign boxes.
13. Double ends for foreign boxes.
14. Method of nailing (hand vs. machine).

With all of these computations, you can readily understand why they spent the time they did to set each standard. Their complex method also necessitated an expensive check by their supervisor to catch errors.

If we analyze this problem a little further, it becomes obvious that we are dealing with only four variables. They are length, width, depth and type (foreign or domestic). Thus we had a very limited number of factors.

My first step was to reduce their data to a multi-variable chart, made in 5 per cent increments related to length, width, depth and type of box. When this was completed, it was possible to set a standard in 30 seconds with fewer errors than they had been making. When we compare this with the average time of 90 minutes under the old method, we have a saving of 89½ minutes per standard.

This analysis pointed out one other very important fact. It was that, although the original data appeared to be complete, when put together, I found that many of the component elements did not cover the complete range of box sizes. Too many studies had been taken on the usual sizes but not enough on the extremes.

Don't think that you must wait until you have standards that require two hours to set before you should consider using this simplified method. Such solutions are ideal for job shop work where speed is an absolute necessity if you are to get any coverages.

Recently, I was faced with a problem of this type and set up a multi-variable chart to handle it. By the conventional method, it took ten minutes for a timestudy engineer to set a standard. Now, the standards are being set in

twenty seconds by my secretary who has had no timestudy training.

This operation is comparable to that of winding springs and includes the following variations.

	Variable Range	
	Minimum	Maximum
1. Diameter of wire	.016"	.028"
2. Overall length of spring	2⅝"	24⅝"
3. Length of straight ends	½"	2"
4. Mandrel Diameter	3/16"	⅜"
5. Pieces per container	200	700
6. Number of coils	18	119
7. Lot size	10	15,000

From these details you can readily see that we have job shop conditions. Although this is true, we do have many common factors. The primary one is that all parts are springs. Also, within a given range, we have a specified method. Further analysis revealed that all elements could be related to the following factors.

1. Overall length of wire
2. Length of wire to be coiled
3. Wire Diameter
4. Mandrel Diameter

After these relationships were established, our solution was set up like that shown in Fig. 1.

In this example, you can see how simple it is to set a correct standard in a minimum of time. Besides, you can set such standards without tying up your highly skilled and high priced timestudy engineers.

By such charting methods, you can lick your cost of setting standards for either job shop or high production conditions. In addition, you will have turned out results that are completed and that more nearly reflect your engineering ability.

Probably the greatest advantage of this method is in the reduction of grievances. This is possible because we are consistent throughout the range of the operation. Inconsistency can cause us more grief than any other factor in the field of work measurement.

Again, to use this better method in standard setting, we are not doing anything that is new or has not been tried and proven over a long period of years. In fact, we should be ashamed of ourselves for not making more use of this technique that has been written up and is available to industry.

Overall Lgth. Of Wire ----- Minus 2 Ends = ------ Lgth. To Be Coiled

Wire Dia.	Mandrel Dia.						
.016 - .019	3/16	1/4	5/16	3/8			
.0191- .022		3/16	1/4	5/16	3/8		
.0221- .025			3/16	1/4	5/16	3/8	
Etc.			Etc.				

Lgth. To Be Coiled In Inches						Std. Mins. Per Pc.
					2.4-3.0	.087
				2.4-3.0	3.1-3.6	.091
		2.4-3.0	2.4-3.0	3.1-3.6	3.7-4.2	.096
2.4-3.0	2.4-3.0	3.1-3.6	3.1-3.6	3.7-4.2	4.3-5.4	.100
		Etc.				Etc.

Figure 1. Here is a simple chart for setting standards in 30 seconds that is in dittoform to save writing.

Book Review

Cases in Management

by Henry M. Cruickshank and Keith Davis, Homewood, Illinois
Richard D. Irwin, Inc., 1954,
221 pages, $4.35

Although this volume of case studies was prepared primarily for college-level courses, it contains many problems which can be used for industrial discussion groups and individual study. The problem and information are presented briefly, about two pages each, but with excellent readability and emphasis on the key facets of the problem. The fields covered include those normally included in industrial engineering plus organization, personnel and supervision. This is an excellent book for those who prefer the case study approach to discussion and learning. However, no solutions are given and the reader must select for himself the correct solution without being able to verify his answer except from his own experience.

OPERATIONS RESEARCH

(Continued from Page 11)

A Check List For Operational Investigations

Formulate the problem in decision-making terms

1. State the nature of the problem.
2. Formulate a set of objectives.
3. Propose alternative means of meeting these objectives.
4. Set some goal, or put some value on objectives.
5. Determine the variables in the problem.

Use A Model

6. Develop a model to simulate the operation under study.
7. Test the model using collected data and the principles of statistical inference. Assume numerous situations, observe the outcomes and their probability.

Note results of the decision

8. Formulate a decision, or indicate quantitatively which is the best set of decisions. Formulate the practical application of the decision.
9. Follow through with the application of the decision. Make the requirements of the application simple, so that operators can handle it.
10. Feed back data from experience; look for new variables or factors. Adjust the decision to compensate for operator difficulties, competition, etc. Repeat the whole series of steps (1-10) until a satisfactory outcome is achieved. Continue to monitor the process or operation in practice to assure that it remains satisfactory.

Summary

Operations research is a method of inquiry designed to evaluate decisions effectively in complex situations.

To show why the operations research method is useful, we discussed some simplified elements of decision theory and noted the differences between simple and complex problems. The main reason for using operations research, we noted, was because of the increasing complexity of operational decisions.

We noted that the operations research way of looking at problems—call it by any name you like—is the outcome of a trend in scientific thought which began many years ago.

Finally, we described the nature of decision models and observed a possible step-by-step procedure for investigation of operations.

In this paper I purposely stressed the background and meaning of operations research—the "why" of many operations research techniques you see in the business and technical press. For those who are interested in specific analytical techniques, data gathering methods, and models described in the literature, a bibliography is attached.

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(Continued on Page 25)

The Ethics of Engineers

By Stephen C. Pepper

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This subject was not of my own choosing, which is, I think, all to the good, since it channels one's thoughts in uncustomary directions.

First, I want to say that I don't think there is a special ethics of engineers. The ethics of engineers and that of mechanics, lawyers, carpenters, doctors, and ministers is all the same—and the same on weekdays or on Sundays. What is morally right in one profession is morally right in another, and in one season as well as in another.

There is, however, a particular liability, a particular area of temptation and tendency to ethical weakness in every profession. I think that is what the present topic is designed to bring out. What is the particular ethical danger to which the engineering profession is especially susceptible? Of course, the opposite would constitute the particular virtue of a highly meritorious engineer. But this virtue is more easily detected in the vice for which it compensates.

So let us turn our thoughts to this problem. But first it would be well to consider briefly what ethics means. The following is, to my mind, a fair initial definition of the subject: *Ethics is the study of the criterions for the evaluation of human conduct.* That is to say, ethics studies what is good and bad, or right and wrong in the acts of men, and the grounds for these judgments. It is implied that men's actions ought to conform to these grounds of judgment. So, ethics is much concerned with questions of obligation and duty.

There are a good many ethical theories. Let me say at once that I have no confidence in any theories that appeal solely to infallible authority, or to the *a priori*, or self-evidence, or indubitable certitude. For such appeals are self-defeating. One infallible authority contradicts another, one claim of indubitable certitude even by most highly respected men is met by a contrary indubitable certitude by men of equal standing. Anyone who sees this sort of thing happen a number of times, cannot but lose confidence in all such tests. So I recommend throwing out all appeals to certainty. That greatly reduces the field of credible theories. Only those theories have to be considered which appeal to empirical probability and evidential corroboration.

Even within these empirical boundaries there are several alternatives. I will choose the one, however, that seems to me best evidenced, to lay out before us the coverage of the kinds of objects that fall within the ethical field. This is a widely held theory with a long ancestry—the so-called interest theory of value.

You will notice that we use the word "good" in an ethical sense of three rather different but closely related things. We speak of *good acts*, of *good men*, and of *good societies*.

Suppose I begin with good acts. There appears, on examination, a stratification of good acts. These are defined by the operation of distinct selective processes which may be called selective systems.

The simplest of these selective systems is that which determines the relation of means to end, the relation between an instrumental and terminal act. Consider an impulse to go to the beach. Here is a drive tension with a consummatory satisfaction in the warm sunshine on the beach and a cool swim in the water. This consummatory satisfaction is good in itself, a terminal act in the release of drive tension.

But now notice that this consummatory satisfaction functions as a selective criterion for the goodness (or badness) of all the instrumental acts which are employed to take me from my home to the beach. If I failed to glance at the gas tank gauge, and run out of gas on the way, that would be a bad instrumental act. If I take a wrong turn not having made the suitable inquiries or not having looked at a map, that would be a bad act. If I drive too fast and am arrested or have an accident, that would be a bad act. For all such acts delay the achievement of attaining the terminal consummatory satisfaction. Note also that the only motive for the instrumental act is that of attaining the consummatory act. The very drive that is awaiting release in the consummatory act is the drive that charges the instrumental act. The dynamics of learning depends on this fact. An *error* in an instrumental act is eliminated as soon as an organism is convinced that the act does not lead to the terminal act. The charge on the instrumental act is identical with the charge awaiting release in the consummatory act. If the instrumental act is in error and in fact does not causally produce the terminal act, the organism rejects that act forever. It turns out to be no good. That is to say the attainment of the terminal act is empirically discovered to be the criterion for the goodness of the instrumental act. A person *ought* to choose a means which will lead to the end. Why? Because the charge on the means, the motivation in selecting it, is the attainment of the end. If with this motivation an unconducive means is chosen, the failure of the means to reach the end factually declares the selection erroneous and bad.

I dwell on this means-end relationship between the instrumental act and the terminal act, because it so transparently exhibits the nature and dynamics of a selective system. The system in its structure contains its criterions of selection, its dynamics of choice. In terms of the system certain acts are accepted and so implicitly judged good and certain acts rejected and implicitly judged bad.

Now there is also a selective system within the consummatory field. This need not delay us in our present ethical problem. But it is very important in aesthetics. There is a tendency for an organism so to act in the consummatory field as to maximize his satisfaction there. If you lie down in the sun on the beach and find the shadow of a bush cooling your body, you will move over into the sun. You will move in and out of the breeze to what is most satisfying. When you regulate the loudness and the tone of your radio for *best* reception, you are performing selective activities within the consummatory field. The artist does the same thing on a vastly more complex scale. This is not strictly means-end activity. It is a maximizing of the end activity.

The next selective system is that of adjusting conflicts among a number of different purposive acts in a single person's behaviour field. This commonly referred to as a conflict among ends. Considerable study has recently been made of selective action in this field. Roughly, the selective tendency is towards a resultant effect to maximize the total satisfaction available within the behaviour field. There is a time element involved, too, however, in terms of the consequences. The field involves means to future consummations as well as present ends, and the reality of the environing situation determines good judgment in the resolution of present tensions. A misjudging of the situation and its consequences comes back upon the organism in pain and punishment and establishes an error in terms of the very dynamics of the system, just as in a simple means-end act.

Then, fourth, is the social situation in which a number of different persons with their own personal interests require cooperation and compromise for the maximum collective satisfaction.

Fifth should be mentioned a man's personality structure which controls the drives he releases in a situation, the things he is interested in, and which

is itself subject to an integrative tendency.

Finally, there are cultural patterns which are selective systems determining what is or is not approved conduct in a man's society, and which are themselves subject to adaptive selection from the physical and social environments in which they are operative. These various selective systems are active as criterions of conduct. Different empirical theories of ethics stress one or another of these.* I would suggest that none of these can be neglected and that the relations of priority of selection among them is a major ethical concern. Under certain conditions, I would say, certain of these acquire priority, under other conditions others. For instance, under emergency conditions adaptive selection takes priority and demands a relatively efficient, centralized social pattern and some restriction on individual freedom; whereas under peaceful and prosperous conditions, a decentralized pattern giving priority to freedom of personal choice (that is, to the individual behaviour field as a selective system) becomes appropriate and gains precedence.

With this brief description of the empirically verifiable ethical criterions as a background, suppose we now turn to the topic in hand. What are the special ethical liabilities of the engineering profession? In order to have an object of comparison, and also to protect me a little from a possible suspicion of bias, I shall first direct such a question upon my own line of work, that of the professional scholar.

What I propose to do is to ask what in the activities of scholarship (and presently of engineering) is likely to lead to certain excesses which will be negatively evaluated by the various empirical ethical criterions just indicated.

Now, there is a well-known name for the great danger to which absorption in scholarship is liable. It is pedantry. What is pedantry? It is such excessive absorption in the particular end where the scholar finds his greatest satisfaction that he fails to be interested in anything else, or to consider the bearings of his particular specialty of research upon other areas of human interest. He commits, in a phrase, *the fallacy of neglect of context.*

In respect to the means-end selective system, this signifies that something that was once a means for the scholar and is a means still for most men has become an end for him, and has crowded out all other ends from his life. His whole life resolves about a particular vitamin, or a particular decade in Roman history, or a particular word root in Sanscrit. He ceases to have any interest in music or literature or in travel or people or even in food or sport and hardly in his family. He is only happy in his laboratory or study among his notes and books. He may acquire considerable fame as a scientist or scholar. But even his scholarship will probably suffer from his exaggerated magnification of his end, and his failure to see its relationships with other things that give it its significance.

What does this do to his behaviour field? We have seen already what it does. Where more balanced men look out on the world with an alert eye and a variety of interests, he is blind. He sees only the books in the windows, and only those whose titles bear on his infatuation. He has lost the horizon of the world from his field of response, and walks with his eyes on the ground.

But, worst of all, he has lost judgment, a sense of proportion, a sense of the relative significance of things, and especially of the human importance of what he is doing. He has probably lost his sense of humor.

And what about his social relationships? He becomes a sort of intellectual hermit though he inhabits a large campus. He has lost most of his human relationships. He is considered queer, and he is queer. He has only one topic of conversation and this soon becomes tiresome to all but others expert in his specialty. He may be a good teacher of his specialty. But if he is not, and cannot get in contact with his students, he becomes scornful of good teachers, and suspects them of "popularity." His counsel is unreliable and often harmful because he has no breadth of judgment. He finds social duties uncongenial and his association with others frustrating and craves still more the solitude of his one engrossing interest.

But his personality? As an able scholar, he has of course the admirable skill and intellectual integrity of any well trained research man. But he is not a well rounded, well integrated man. His sacrifice of so many natural interests to this one narrow scholarly end is not entirely healthy. So much loss of human relationships is but a symptom of much deep frustration frozen into his character. He is not much of a man. Nearly all his potentialities are cut out but one. He is reduced to his single narrow specialty which has become the solitary goal of his life.

Lastly, how does he fit into his cultural pattern, the institutions of his society? He fits in precariously. He will be tolerated indeed, if he is lucky, he will be honored in a protected area of his society such as a University—provided his specialty happens to be socially valuable either through some scholarly tradition still respected or because there happens to be a use for his results at the time. But not being an adjustable man, his value to society is at the mercy of the chance that his specialty fits the cultural pattern of his time.

Now you may say, no such man exists. Just look around at our friends and colleagues in the faculty club. What one of these fits this picture of an ideal pedant? Strangely enough, it just may happen that you will be surprised. With the foregoing picture in mind, he may actually rise from the next table. But this is not the point. The point is rather, that here we see a tendency to which scholarly men are liable. You see its evidences sometimes in group decisions where something a little like a mob spirit prevails, and these men's collective response gets averaged down to their prevailing vice. Have you noticed how difficult (or impossible) it is to get a group of high powered specialists in a University like this to combine on a reasonable liberal arts program for the undergraduate student? Every specialist there speaks for the supreme value of his specialty and nothing less than half a student's total time will barely introduce the student into the rudiments of each subject. So, the student's program is squeezed out in a series of compromises between these grinding specialties.

So much for the pedant and the prevailing vice of the scholar. What now may be the prevailing vice of the engineer? Hunting for an unpleasant word to name it, comparable with pedantry, I suggest it may be servility.

The pedant goes to excess with an end. The ethical danger for an engineer is that he may go to excess in his concentration on means. All his training and all his life is concerned with human instruments—bridges, dams, dynamos, roads, canals, harbors, sewers, and filtering plants, mines, wells, and refineries—all instruments for ends which have been set by other men, not the engineer. Inevitably and properly, the engineer becomes absorbed in the techniques of producing means with the highest efficiency for attaining ends . . . whatever these latter may be. He doesn't seem to need to think of his ends, but only about the means. This is indeed the very nature of his job.

But suppose this concentration on the means is carried to an excess. What can we expect then? We have a man who is always offering his services for any end and never asking about the significance of the end. This leads to two possible evils: (1) a failure perhaps to appreciate ends at all, and (2) a tendency to think that the end justifies a means, so that if the means attains the end no more need be considered.

Let us follow this ideally bad engineer through the various selective systems we discriminated earlier.

In the means-end field he concentrates upon the means, as we have seen, and admires efficiency and has little respect for people who waste their time in consummatory satisfactions. In the aesthetic field he wants to know what use

*Specifically, traditional hedonism stresses means-end and the behaviour field and the maximizing of individual satisfactions; contextualistic and pragmatic theories, like John Dewey's, stress the social situation as the ethical criterion; self-realization theories and various forms of idealism stress character integration; cultural relativity theories stress the selective control of cultural patterns; evolutionary ethical theories stress the selective control of environmental adaptation.

artists have and will perhaps allow they have a place as entertainers for the tired executive.

In the next level of the behaviour field where there are conflicts of purposes, the weakness of the ideally bad engineer shows in his willingness to let ends take care of themselves. He offers his services to whoever shows he needs them—whether an industry or a department of government. His to do and not to question why. He will see with logical clarity the justification of means to end. He will rarely be drawn to consider that the end does not justify the means in a field of diverse ends. Since this may sound even here as a paradox, let us ask why. The reason is that the selection of a means for a certain end may be so destructive of other ends in the behaviour field, that it is better to give up the original end altogether. It is another instance of the *fallacy of neglect of context.* The pedant shows it one way, the servile engineer another. The everyday expression we have for this phase of the fallacy is "throwing the baby out with the bath." If the end is to empty the bath tub, why clearly throw the water down the drain? But what if a baby happens to be in the tub? And sometimes the baby is not obviously to be seen. And when the baby is thrown out and the howls begin, it is not an adequate excuse to say that you were just doing what you were told—emptying the tub. There are no means that are not connected with ends other than the immediate end in view, and what one ought to do in a behaviour field involves all the ends, and never just one alone—or almost never. But the ideally bad engineer believes himself particularly keen in isolating the end in view and serving that end with the highest efficiency. In this behaviour he is as bad as the pedant.

And now go to the social situation, the ideally bad engineer is the idolator of efficiency. He tends to treat men as means and not as ends in themselves. He is likely to be impatient of individuality and a stickler for conformity, unless some use can be seen for unusual actions. That the most efficient way of getting something done offends the sensibilities of a lot of individuals will not get much consideration. In going across a bridge, why should autoists be given a view of the water and boats below? That would only reduce the efficiency of the driving, and has nothing to do with the service of the bridge.

And the man. This ideally bad engineer would clearly be a man of achievement. Like the pedant he may attain great honor in his society, because of his instrumental achievements. But he is not a man of sensibility or discrimination. He will be so *blind* to what he has not got and he will be so aware of the objective and measurable utility of his achievements that he may be very dangerous to his society. But this is getting ahead to the next point. As a man he is only partly integrated. Half of him is as dried up as with the pedant. Achievement may even become a mania with him. He cannot really enjoy nature, or art, or books, or even himself. His total resource is in the doing of something—in fact, doing anything, the bigger the better. So he has actually very little judgment or breadth. And like the pedant, he has probably also lost his sense of humor.

Lastly in the area of cultural pattern and ideals, this ideally bad engineer will be exceedingly conservative and conformist for the most part, accepting the ends his social pattern gives him. For he has little interest in matters of policy or long range social ideals, being trained to serving men faithfully in giving them means for whatever ends are put up. But if occasionally the ideally bad engineer looks out over the total social field and undertakes to design a policy, then he is more dangerous than ever. For the inefficiency of social relationships in the variety of men's impulses and enjoyments and pursuits is glaring. So the ideally efficient society, a managerial society, or a technocracy inevitably emerges, with all the engineering techniques and power to back these up. And the ideally bad engineer, being as blind in his way as the pedant in his, absolutely cannot see what is wrong with such ideals. Of course, the only thing wrong with them is that they are all means and no ends—all perfectly instrumental and devoid of the consummatory satisfactions—or almost so.

Having now said these things, I must be prepared for the counterblast. As with the pedant, don't expect to see the embodiment of this ideally bad engineer here among us at these tables. But I would simply ask you to consider if this is not the sort of thing an engineer must guard against.

And now for the other side of the picture: the ethically fine engineer. He is obviously the man with all the technical skill and practical outlook which his thorough professional training offers together with the judgment and human consideration of the many interconnected ends and persons involved along with the means of serving them. He does not make the easy error of neglect of context. He is not servile but serviceable, and so guided no man could be better equipped to be thus serviceable.

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by Charles L. Jamison,
Prentice-Hall,
New York, 1953, 580 pages, $8.65

Many industrial engineers find themselves dealing with matters which involve business and management policy which fall outside the scope of industrial engineering. The general principles of making and carrying out these policies are covered by Prof. Jamison who then discusses specific policy problems of the various functions of a business. He also includes material on executive training, staff operations, and remuneration.

BOOK REVIEWS

A History of the School of Engineering of Columbia University
by James Kip Finch, New York,
Columbia University Press
1954, 138 pages, $2.75

Although this is a history of a single school of engineering, it devotes considerable background to the development of the engineering profession. Prof. Rautenstrauch and Industrial Engineering are brought in briefly. Dean Finch has produced an interesting history of Columbia's School of Engineering and its faculty. In a scholarly manner, he fits Columbia's development of engineering into the growth of the whole profession. He also emphasizes Columbia's belief in a general college education as well as in specialized professional training.

The Dynamics of Industrial Management
by Raymond Villers, New York,
Funk & Wagnalls Company, 1954
546 pages, $6.25

Villers approaches industrial management with the hypothesis that maximum decentralization is desirable consistent with the benefits of specialization. He believes that only through decentralization can industrial organizations give the individual the personal satisfaction that he desires. While the author proposes no new or radical solution, his point of view and discussion are quite stimulating and pertinent.

OPERATIONS RESEARCH

Proceedings, Seminar sponsored by Railway Systems and Procedures Association, technical assistance from Operations Research Office, The Johns Hopkins University.

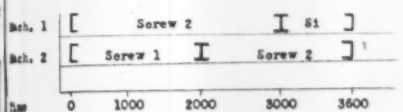
Scientists, Industrial Engineers, Railroad Executives tell about the application of Operations Research and Industrial Engineering techniques to the military, transportation and manufacturing. Includes many case studies. Papers presented on inspection operations, overall company planning, information handling, rail-truck co-ordination and other business problems. Learn how to select and train an Operations Research group. One Executive remarked "If this is Operations Research, I am all for it." Another said that analysis of operations in the next ten years would save more for Railroads than has the diesel. Illustrated, 131 pages. $4.50. Railway Systems and Procedures Association, P. O. Box 514, New York 8, N. Y.

Mathematical Methods in Management Programming: Part II

R. T. Nelson [2] and M. E. Salveson [3]

Part I (published in the March, 1954 issue) treated some preliminary problems in managerial programming of production in order to illustrate some of the potentialities of mathematical methods. We wish now to consider two particular problems associated with use of these methods. These relate to the fact that: 1. there exist technologically determined orderings on the sequence in which production processes must be carried out on any commodity, 2. usually a commodity can be processed in one and only one machine tool at a time, and a machine tool can handle no more than one commodity (or other specified number) at a time. These technological concepts are discussed more fully in (5); they are formalizations of familiar engineering facts. In addition, it often is found that at some levels of production, certain commodities may be produced most economically in "batches" or lots rather than continuously as the assumptions of the model in Part I implied.

In order to examine these concepts and their impact on methods usable, for management problems, let us reconsider the problem which was solved in Part I, and its computed program on a Gantt chart as follows:



Analysis of this chart indicates that, according to the limitations on machine capacity, the computed program is schedulible within the specified time period. However, note that the total amount of time that the whole lot of screw 2 is in process is greater than the amount of time available during the period. This is further illustrated by the following tabulation:

	Screw 1		Screw 2		Total Machine Load
Mach. 1	(327 × 2 =) 654	+	(982 × 3 =) 2946	=	3600
Mach. 2	(327 × 5 =) 1635	+	(982 × 2 =) 1964	=	3599
Total time screw is "in-process"	2289		4910		

The overlapping of operations 1 and 2 on screw 2 could be resolved by "splitting off" some of the lot and moving it to the second machine before the processing is complete on all units in the lot at the first machine. However, split lots is an experience, if at all possible, to be avoided. It increases costs of production control disproportionately—it increases cost of record keeping; increases need for expediters, dispatchers, and inspectors; it increases costs of material handling, etc. Hence, for these circumstances, we require a method that will assure that the computed program is schedulible. Preliminarily, we can accomplish this requirement in this problem by the following revised model:

$$\text{maximize:} \quad \sum_i a_i x_i ,$$

$$\text{subject to:}$$

$$(1) \qquad \sum_i b_{ij} x_i \leq c_j , \quad j = 1, \cdots, m,$$

$$(2) \qquad \sum_j b_{ij} x_i \leq c_i , \quad i = 1, \cdots, n,$$

$$x_i \geq 0,$$

where m is the number of factors in limited supply (machine tools, etc.), and n is the number of commodities.

The second set of restrictions assures that, in the particular problem illustrated here, the resulting program is schedulible under the requirement of not splitting lots. The problem now is solvable by the same methods presented in Part I. Indeed, the solution to that problem with these additional restrictions becomes:

$$x_1 = 432$$
$$x_2 = 720$$

and the value of the objective function decreases to

$$3 \times 432 + 4 \times 720 = 4176.$$

However, if we do not include these restrictions but, instead, scale down the originally computed program so it can be scheduled as follows:

Screw 1: not scaled 327

Screw 2: $\frac{3600}{4910} \times 981 = 704.$

We find that the value of the profit function is decreased more than if the alternative formulation is used, as follows:

Value of the objective function

1. As computed in the model that considered only machine capacity restrictions $P = 4909$
2. As computed in the model that considered both sets of restrictions $P = 4176$
3. As computed by scaling down the program in (1) above $P = 3797.$

The object lesson from this illustration bears emphasis: An under-restricted model of a programming problem usually will result in an over statement of the potential profit. When it is found (as usually will be the case) that the computed program is not schedulible, the result may be an unjustified loss of confidence in the method.

We now can predicate a more general statement on the above model. Consider the case in which lots may be split in discrete increments, i.e., at individual or integral units of the commodity being processed. The restriction on the in-process time of the commodity becomes:

$$\sum_{j \in I_j} b_{ij} x_i + \sum_{j \in I_j} (m_i - 1)\, b_{ij} \leq m_i c_i , \quad i = 1, \cdots, n,$$

Where m_i is the number of elements in the set $\{ j \in I_j \}$, that is, the set of operations, j, on commodity I. These restrictions reflect the fact that each unit of a commodity must be fully processed through one operation before moving to the next operation. Hence, there is a staggering of the time of processing even if the lots are split their maximum amount, i.e., at every discrete unit. In most cases of job or semi production shops, the maximum split will seldom be sought. Instead, each lot in process commodities will be in an active operation only a small fraction of the time. Then, we could write

$$\sum_{j \in I_j} b_{ij} x_i \leq \theta_i c_i , \quad i=1 \cdots, m,$$

where θ_i is an arbitrary constant, $0 \leq \theta < 1$, empirically determined from the shop and reflecting the percentage of the time which the ith commodity will be in-process "on the average." For example, if any θ_i takes on a low value, it means that commodity is actively in-process a relatively small percentage of the time. In some job shops we find that $\theta \cong 1/20$. Also, we find that $\sum_i \theta_i \cong K$ hold reasonably well for any shop. This means that we have within the model an arbitrary parameter which can be the basis for further examination of the profit and production function under alternative programs.

The above method of incorporating further restrictions in the model assures that our computed program will be more schedulible. While it does not fully assure that a computed program will be schedulible, it will approach this desideratum. In general, it will select more different commodities for production, but a smaller number of each type than would otherwise be the case. Coupled with this is its simplicity of formulation. In effect this method of representation uses empirical experience on what fraction of the time commodities can be programmed for processing and still assure that the program is schedulible. It thus avoids the combinatorial problems of exact scheduling which we discuss next.

The effect of technological orderings and of the restriction against splitting

[1] Prepared while under contract with Logistics Branch, Office of Naval Research. Sincere appreciation is expressed to Prof. I. M. Singer, Dept. of Mathematics, U.C.L.A.

[2] Research Engineer, Management Sciences Research Project, University of California, Los Angeles.

[3] At time of preparation: Project Director, Management Sciences Research Project, University of California, Los Angeles, and consultant to Logistics Research Project, George Washington University. Now: Procedures Research Manager, Business Procedures, Major Appliance Division, General Electric Company.

lots on the schedulibility of computed programs is now explored briefly. For example, if in the Gantt Chart both screws had the same ordering on the sequence of their operations and if all units of each must be completed in a single lot, the reader can easily verify by inspection that the computed program would be even less amenable to scheduling.

A sample problem is presented now to illustrate certain techniques in scheduling for handling problems of this type. It is slightly larger than the earlier problem in order to make it interesting and is due primarily to the former author. It illustrates a procedure for:

1. Computing the optimum feasible schedule for a *given permutation* and set of commodities each with a technological ordering on the sequence of processing.
2. Evaluation and comparison of the possible permutations.
3. Evaluation and comparison of alternate routines.

Consider a shop in which two commodities i = 1, 2 are produced on three machine tools j = 1, 2, 3.

As before, the time required for processing one unit of commodity i on machine j will be denoted by b_{ij}.

Assume: 1. Unit operation times as follows:

	Machine Tools j = 1	2	3	
Commodities i = 1	6 min.	5 min.	3 min.	Unit profit = \$4
2	9 min.	8 min.	1 min.	Unit profit = \$5

2. The time period for which production is to be scheduled includes 1000 minutes

3. Routings for the jobs (Manufacturing Outlines):

$$(1,1) < (1,2) < (1,3)$$
$$(2,1) < (2,3) < (2,2),$$

where "<" is read "must precede." In the following discussion the ordered pairs (i,j) which denote the processing of commodity i on machine j, will be further simplified in notation to "ij." x_i denotes the unknown quantity of comodity i to be produced. Thus, each operation ij will require $b_{ij}x_i$ minutes as follows:

	j = 1	2	3
i = 1	$6x_1$	$5x_1$	$3x_1$
i = 2	$9x_2$	$8x_2$	x_2

There are two operations to be performed on machine 1: 11 and 21. There are two possible permutations of these operations, either 11, 21 or 21, 11 i.e., either commodity 1 is processed on machine 1 first, and then followed by commodity 2; or vice versa. The same consideration for machines 2 and 3 yield $2 \times 2 \times 2 = 8$[4] possible permutations as follows:

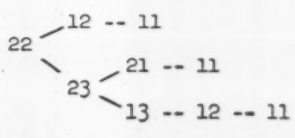
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
j = 1	11,21	11,21	11,21	11,21	21,11	21,11	21,11	21,11
2	12,22	12,22	22,12	22,12	12,22	12,22	22,12	22,12
3	13,23	23,13	13,23	23,13	13,23	23,13	13,23	23,13

Given a permutation from this set, we first will consider methods of computing the optimum feasible schedule. Take, for example, permutation P_1. In the following analysis, the technological restrictions on the routing and the permutation taken must be considered simultaneously in computing the program.

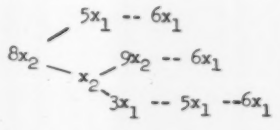
The technological ordering, T, and the permutation P_1, are as follows:

T	P_1
11, 12, 13	11, 21
21, 23, 22	12, 22
	13, 23

If the operations ij are mapped in time (for example, by plotting on a Gantt Chart), the only operations which (from the point of view of the technological restrictions, T, alone) could be carried out last are 13 or 22. From the permutation, P_1, only 21 or 22 or 23 could be last. Considering both restrictions simultaneously, we find, therefore, that operation 22 must be the last to be carried out. Hence, the last operation to be completed will be commodity 2 on machine 2. We next ask what operations may determine the starting time of 22, that is, must precede 22 immediately. From T, 22 can be started only after 23 has been completed; from P_1, it can be started only when 12 has been completed. Considering both T and P_1, 22 can (and, of course will) be started as soon as the last of 23 and 12 is completed. Since we do not know the quantities of each commodity that will be produced, we do not know whether 12 or 23 will finish the later. Therefore, we must allow for both possibilities. The same procedure is repeated to determine the starting times for each 12 and 23 and is continued until the elements which have no precedents are reached. This is the end point because all such elements will be started immediately at the beginning of the time period. A schematic illustration of the procedure is as follows.[5] Read from left to right, to give last operation to first.



Substitution of $b_{ij}x_i$ = ij in the schematic illustration gives:



It is assumed production is started at the beginning of the production period and will be completed when the final operation is completed. One of the paths in the schematic diagram is the longest, depending on the values taken on by the variables x_1, x_2. Since we do not know x_1 or x_2 at this time, we do not know the longest path. However, if all paths are so restricted that the sum of the time required in each is less than or equal to the time available in the period, then regardless of which may be the longest path we are assured that production will be completed in the available time.

For this problem the restricting inequalities become, one for each indicated path, as follows:

$$11\,x_1 + 8x_2 \leqq 1000$$
$$6\,x_1 + 18x_2 \leqq 1000$$
$$14\,x_1 + 9x_2 \leqq 1000$$

Any program (x_1, x_2) satisfying these restrictions can be scheduled and will satisfy T and P_1; it is termed feasible.

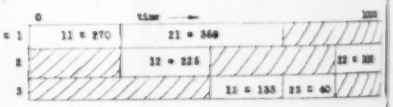
To find the optimum program now becomes a problem of maximizing a linear form subject to a set of linear inequalities. The simplex method as discussed in Part I is used again to obtain the optimum program. Algebraically, the problem is:

Maximize:
$$4\,x_1 + 5x_2$$
Subject to:
$$11x_1 + 8x_2 \leqq 1000$$
$$6x_1 + 18x_2 \leqq 1000$$
$$14x_1 + 9x_2 \leqq 1000$$

The optimum feasible program for T and P_1 is:

$$x_1 = 45$$
$$x_2 = 40$$
$$\text{Profit} = \$380.$$

The following Figure illustrates the feasibility of the program.



For comparative purposes, the ordinary linear inequality formulation of the problem neglecting the routings and using only machine-hour restrictions:

Maximize:
$$4x_1 + 5x_2$$
Subject to
$$6x_1 + 9x_2 \leqq 1000$$
$$5x_1 + 8x_2 \leqq 1000$$
$$3x_1 + x_2 \leqq 1000$$
Gives:
$$x_1 = 167$$
$$x_2 = 0$$
$$\text{Profit} = \$668$$

[4] In general the number of permutations will be: $(m!)^n$ where n = number of machines, m = number of jobs

[5] For practical purposes an equivalent procedure is to list all common first elements from both T and P, then the immediate subsequents of each elements, etc., until common final elements are reached.

However, an attempt to schedule this program in the time available would be futile. This is, of course, because the formulation omitted both the fact that a given lot of a commodity may be in one and only one place at a time and also it ignored the given routings. Consideration of these restrictions means that $6x_1 + 5x_1 + 3x_1 + 14x_1 = 14\ (167) = 2333$ minutes would be necessary to schedule the program computed from the under-restricted model. If the computed mix (167, 0) is reduced to schedulible proportions by scaling down as before:

$$\frac{1000}{2333} \times (167) = 71$$

we find that only 71 units of commodity 1 can be scheduled in the time actually available. This corresponds to a profit of only $4(71) = \$284$ or considerably less than for the program derived considering all relevant restrictions.

If the procedure above is used to compute the optimum feasible program for all possible permutations in this problem, we have a measure on the attainable profit of the various permutations. In this way it is possible to evaluate all (or as many as may be practical) of the possible permutations and to select the one with the highest profit. The following table summarizes these evaluations for this sample problem. The permutations listed as non-feasible in the table are those permutations which are inconsistent with the given routings.

Permutation	x_1	x_2	Profit
P_1	45	40	$380
P_2	67	23	$433
P_3	Non-Feasible		
P_4	71	0	$284
P_5	71	0	$284
P_6	57	22	$338
P_7	Non-Feasible		
P_8	51	33	$369

P_2 is the permutation with maximum profit.

If the production planning department were to list each of the several routings which are technologically feasible for the commodities, the procedure described above would be immediately applicable for each such routing. The maximum attainable profit of each alternative routing thus would provide a basis for comparing and selecting from the several alternatives. Hence, this provides a method for selecting, not only optimal schedules, but also optimal routings, as it eliminates guesswork from the rerouting problem.

Subsequent to preparing this paper, the former author has extended the method to include set up time and transportation time between operations. The latter author has extended the method to programming problems involving further arbitrary, but realistic, restrictions in shop loading and in balancing an assembly line. These will be reported later.

In response to a certain number of requests, further references are mentioned relative to other works in this field. These include:

1. Dorfman, Robert, "Mathematical, or 'Linear,' Programming: A Non Mathematical Exposition," **America Economic Review**, Vol. XLIII No. 5, Part I. Dec. 1953. An excellent expository article.
2. Hoffman, A., Mannus, M., Sokolowsky, D., and Wiegmann, N., "Computational Experience in Solving Lnear Programs," **Journal, Society for Industrial and Applied Mathematics**, Vol. 1, No. 1, Sept., 1953. Review of use of the Bureau of Standards Electronic Computor, SEAC, to solve problems of the linear inequality type.

   The most comprehensive book in this field and one which is especially recommended as a standard reference is:
3. Koopmans, T. C. (ed.) **Activity Analysis in Production and Allocation**; John Wiley, New York, 1951. This text is largely in the language of the economist and the mathematician and will require a certain amount of concentration by the typical industrial engineer.

   If still available, one of the best technical surveys of the mathematics of this field is:
4. Project SCOOP, **Symposium on Linear Inequalities and Programming**, April 1952, mimeographed by Planning Research Division, Director of Management Analysis Service, Headquarters, U.S. Air Force, Washington 25, D.C. Also, a simplex code for Univac has been prepared there.

   An initial formulation of the mathematical problems related to production scheduling is given by:
5. Salveson, Melvin E., "On A Quantitative Method in Production Planning and Scheduling." **Econometrica**, Vol. 22, No. 1, October, 1952.

   A forthcoming book on petroleum refining presents some very interesting and useful results. It will be:
6. Manne, Alan S., **Petroleum Refinery Operations Scheduling.** Manne is at the RAND Corp., Santa Monica, California.

   An interesting similar report on petroleum refining is:
7. Symonds, Gifford H., **Application of Linear Programming to the Solution of Refinery Problems**, Esso Standard Oil Co., P.O. Box 185, Linden, N. J., January, 1954.
8. Vazsonyi, Andrew, "The Use of Mathematics in Production and Inventory Control," Hughes Aircraft Co. Research and Development Laboratories Technical Memo, No. 332, Nov. 1953.

   An excellent analysis of the problem of determining parts requirements to meet a given sales forecast.
9. Dantzig, G. B., "Notes on Linear Programming, Vols. I to VI," RAND Corp., Santa Monica, Calif. An excellent series of memoranda covering relevant mathematical concepts, the simplex computational algorithm, and through to an IBM 701 routine for the simplex method.
10. Management Sciences Research Project, University of California, Los Angeles, (Prof. A. J. Rowe, Project Director), some relevant papers include:

    Barankin, E. W.—"Precedence Matrices."

    Barankin, E. W.—"The Fabrication Scheduling Problem as a Generalization of Ordinary Linear Programming."

    Canning and Salveson—"Automatic Data Processing in Larger Manufacturing Plants."

    Canning and Salveson—"Electronic Production Control."

    Edmundson and McAllisteer—"Early—Punctual Late"

    Jackson, J. R. "A Linear Programming Model for Industrial Scheduling."

    Jackson, J. R.—"On The Existence Problem of Linear Programming."

    Nelson, R. T. "An Engineering Analysis of the Scheduling Problem—Initial Results."

    Nelson, R. T. "Job Shop Scheduling: An Application of Linear Programming."

    Nelson, R. T.—"Setup and Transportation as Elements of A Linear Scheduling Model."

    Salveson, M. E.—"A Computational Technique for the Scheduling Problem."

    Salveson, M. E. "An Introduction to Mathematical Methods in Production Control."

Errata to Part I of this paper:

1. Equation in the footnote on page 13 should read:

$$X_1\begin{pmatrix}1\\0\end{pmatrix} + X_2\begin{pmatrix}0\\1\end{pmatrix} \quad X_3\begin{pmatrix}2\\3\end{pmatrix} + X_4\begin{pmatrix}5\\2\end{pmatrix}.$$

2. Last full paragraph page 13, the word "optional" should be changed to "optimal."

PERFORMANCE RATING

(Continued from Page 8)

formula which negates the time we appear to give by using an allowance."

This, I submit, is fundamentally wrong. Even if the premise were true, two wrongs have never yet combined to make a right, and the premise is not true.

Does a better method for use of the SAM films exist? An analysis of what the films are and can do should lead to an answer. The films represent 5 paces each of a wide variety of tasks. The relative values of each of the 5 paces for each task is determinable by frame counting; the relative values of the "incentive times" for the various tasks has been determined from the pooled judgment of many observers. Therefore, all that need be done to use the films in a given company is to compare the concept of normal as used in the company to the "incentive time" concept used in the manual. This can be done in the following way:

1. Have a group of qualified observers rate all the scenes on one of the films.
2. Determine the average rating for each scene.
3. Multiply the actual cycle time for each scene by this average rating factor to obtain the normal time for each scene. (The normal times obtained for each task should be reasonably consistent if the observers are qualified).
4. Average the normal times for each task to obtain the normal time for that task, in terms of the company's own concept of normal.
5. Determine the ratio of the normal time as thus found to the "incentive time" as formed in the "Manual of Performance Rating" for each task.
6. Average the three ratios obtained to yield the best estimate of the true ratio for the company.
7. Determine the normal times for task shown on other reels by multiplying the "incentive times" shown in the "Manual of Performance Rating" by the ratio of normal time to incentive time as found above.

In this way, normal times for all jobs, in terms of the company's own concept of normal can be obtained without the necessity of indulging in some extremely dubious assumptions and mathematical manipulations.

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Stimulating Job Simplification Thinking Among Hourly Rated Employees

By Harold R. Nissley, P.E.,
Cleveland Heights 21, Ohio

Although the era of the efficiency experts is past, much remains to be done before operators will accept industrial engineering techniques as enthusiastically as larger and larger segments of supervisors accept them today. Why are more and more supervisors accepting motion and time study principles and putting them to work in their departments? There are two good reasons: (1) First they begin to understand what industrial engineering is and what it is attempting to accomplish—for them, for their operators, and for their companies. And (2) intelligent industrial engineering programs integrate more and more of the supervisor's thinking in their formation and in their administration.

It is not enough, therefore, that intelligent supervisors understand the purposes of the industrial engineering function. To operate successfully, such a function should be the product of staff specialists (industrial engineers) *and* supervisors. This does not mean, of course, that the foreman is going to tell the industrial engineer how many and what kind of stop watches to use or what method of standard setting the engineer shall employ. It does mean, however, that the engineer should seldom use "higher authority" for selling his standards or his job designs.

These are common sense rules that most experienced engineers either accept as good working rules or have learned to be helpful in reducing costs and making jobs easier.

Not so successful are the educational efforts of engineers in selling their "wares" to operators. This lack of success is due to several reasons: (1) Marginal industrial engineers[1]; (2) a bellicose local union; and (3) unintelligent management. Usually the strife that surrounds an industrial engineering activity has elements of all three of these factors present.

But the purpose of this article is not to show how to convert an unsuccessful standards or methods program into a successful one. Rather it is to point out what can be done to make a successful methods program even more successful —by enlisting the interest of the operators in such a program.

Some companies have set up formal classes for union stewards and operators in order to give these people the same engineering educational opportunities that their foreman have had. It is hoped, of course, that such classroom effort will bring greater understanding and more harmony about management techniques. But such classroom effort takes time and is fraught with mental resistance (at least at the start).

A few companies have overcome some of the objections to formal class room work for hourly rated people by putting on a series of noon day movies at one end of the cafeteria or in some other suitable place. Some have offered to pay for home study courses of their hourly rated people — or for regular evening class work taken on their own time.

All of these educational efforts should be encouraged. But most of them lack a certain amount of "spice." "Who cares anything about shorter distances?" There are few, however, who are not interested in getting a free lunch. There are few who are not interested in playing some sort of a game at noon time.

Let us put together these psychological ingredients into an educational pie and see what we have. For want of a better name let us borrow one that was used by an Eastern wartime manufacturing concern, QUNCH (quiz-lunch).

QUNCH is the game of answering questions at lunch time. The winners get free lunches. QUNCH can cover a number of areas: Economics[2]; Safety; Job Simplifcation; or anything else.

QUNCH WINNERS GET FREE LUNCHES

This conyest is open only to hourly-rated employees. Answer as many of the following questions as you can and return this sheet (signed) to the cashier before leaving the cafeteria. Winners and answers will be posted tomorrow.

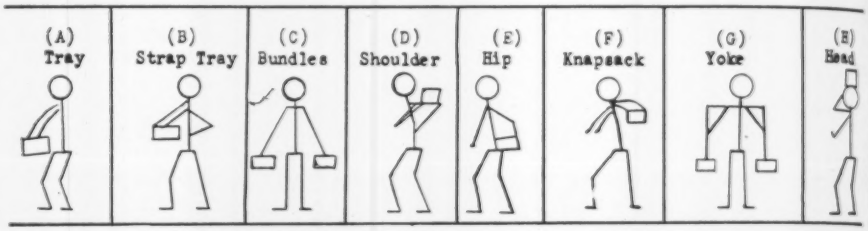
1. A 25 per cent savings in time will yield how much more production -- assuming the same amount of energy expenditure? _____%

2. Smooth round screw drivers handles are faster and less fatiguing than rough semi-flat handles for medium and heavy work YES____ NO____

3. If you slide small flat parts (shaped like pennies) instead of picking them up, it is not only easier but it takes how much less time? _____%

4. Contrasty backgrounds make it easier to do fine work. How much less time would it take to thread a needle with black thread against a white background compared with threading it against a black background?_____%

5. Of the eight methods of carrying loads shown below which is the best or least fatiguing and which is the poorest or most tiring? (BEST:____) (POOREST:____)



6. If a company makes a 5 cent profit for each dollar's worth of goods it sells, how many dollars worth of goods must it sell to recover one dollar wasted in labor and materials in the factory? $_____

7. In the space below suggest a time-saving or money-saving question that might be suitable for future qunch games.

_____

_____

_____

_____

PRINT YOUR NAME _____ DEPARTMENT _____

Because most of the readers of the JOURNAL are industrial engineers let us concentrate in this article on Job Simplification and see how QUNCH might *help* sell motion and time study to hourly rated employees.

A sample QUNCH sheet is shown above. Such a sheet is picked up at the cashier's counter when an employee pays for his lunch (or when he enters the cafeteria). The sheet is returned to the cashier before the employee leaves the cafeteria. Where multi-shift operations are carried on, more than one set of questions would be desirable.

Obviously, if you don't have a cafeteria or most of your hourly rated people do not use your cafeteria, this qunch idea would have to be modified to suit your conditions (including, perhaps, the questions themselves). You may, for example, wish to put such quiz sheets behind the time cards of operators and ask that the answers be turned in before quitting time, if they are to be counted. Obviously, other suitable prizes besides free lunches will have to be offered.

[1] "Marginal industrial engineers" is explained in greater detail in the writer's paper, "Stop Watch Time Study Can Be Accurate and Salable as Tabular Systems" before the Fifth Annual AIIE conference at Louisville, Kentucky, May 5, 1954 and published in the Conference PROCEEDINGS.

[2] See the writer's article, "Qunch: Novel Twist in Training Follow-Up" in the July, 1953 issue of **Management Review**.

(Continued on Page 23)

YOUR IDEAS ARE WORTHLESS

Unless You Can Sell Them

Phil Carroll*

My Physics teacher in High School insisted, "There is no sound if no one is near enough to hear it." Even more pointed is the title of Alexander Heron's new book NO SALE, NO JOB. Just like your company's products, you have to get some one to buy your ideas before they can have any value.

PAY OUR WAY

Industrial Engineers must sell. They cannot carry on without making a fair contribution of new ideas. Enough of these must be put to work before there is created the money to pay their salaries.

To pay our way, we have to get results. How much is a question. Some say three times. Ten times return on the salary each year is the biggest rate I've heard.

Take your choice because that is another subject. The point is that you can pay your way only after your ideas are successfully in operation. For that reason, your career depends upon your success in selling your ideas.

SOURCES OF IDEAS

What you want to sell may be a "brain child" of your own invention. More often, you will be selling the application of some one else's ideas. These may be newly developed or old ideas you see new uses for.

Regardless, you must talk some one into making a start. That may require no more than getting an operator to try your new sequence of work elements. At the other extreme, you may have to persuade some officials to spend a large sum of money. In between are many other types that require approvals.

WHO IS YOUR BUYER

To get approval, you may have to sell your boss—an individual. Sooner or later you may have to sell a group—your executive committee, several bosses or a group of people in your plant operations.

Then too, you have to consider the direction of your sale. Are you trying to sell an idea to someone or group that has higher, equal or lower status? Here I refer to your prestige—your standing in your own organization. Another side of your sales problem is brought out by the question, "How much experience do you have in comparison with the person or group you hope to sell?

Let me give you a typical example. I was talking with the president of a company that built products of sheet metal. He asked me, "Have you ever had experience working in a sheet metal plant?" I said, "No, only where sheet metal work was done by maintenance departments." To this he countered with, "What makes you think you can set standards on our operations?" My reply was, "Because I've had a great deal of experience in working with people."

Many people in industry put great store in experience. Yet, I maintain that you can't live long enough to get all the experiences that are necessary to overcome this argument. So you must find other ways to make your sale.

WHAT IDEAS

Then, of course, there is the question, "What kind of an idea do you want to sell?" There are all sorts. Are you trying to sell an idea that is new and untried? Are you hoping to sell a change where you have some precedents to go by? Or are you thinking of selling your boss on the idea that you deserve a raise?

This phase breaks down further into what you might call selling little or big ideas. Does your proposal affect an isolated problem or does it involve a whole series? Will it cost a small amount or many thousands of dollars? Will it upset the habits of a few people or a whole plant?

ON A TRIAL BASIS

You can say, and I agree, that a major change can be tried out on a small scale. Many that I know about are approached exactly that way. You get approval to apply your idea to one department or one procedure. But then you have another question to answer. Can you return to the original basis if your installation fails?

For example, suppose you were convinced that your company needed Production Control. Let's assume that you were successful in selling the idea and got approval to go ahead in one section of the plant. After you have set up your schedules and issued them, there are many interruptions, changes and breakdowns. You try again and again. Your enthusiasm increases with the challenge. But finally your boss says, "Too much system."

After such an attempt, there may be very few if any problems of reverting to the old method. But imagine those that could arise if the idea you sold were job evaluation, profit sharing or wage incentives, to name a few. How could you return to your starting point?

SALESMEN ARE BORN

You can't escape selling by saying, "I'm not a born salesman." That's only a dodge. How do you know? Here's an example that should convince you.

The other night riding home on the train, a neighbor told me of a skilled and well-paid accountant who lost out in an organizational shuffle. This accountant went to clinics to get placement guidance. He had all the tests and analyses of the kinds of work he should do. In this preparation for job hunting, all his advisors told him that selling was one type of work he should not enter.

The accountant tried many places for a suitable job in his own field and failed. Finally in desperation, he took a job selling for one of our best known producers of accounting machines. This man has topped his company's list of salesmen for five years, according to my neighbor.

How can this happen? What enables a man to head his company's list in selling whose aptitudes were seemingly unsuited to selling? I don't know the answer any more than you do.

INTEGRITY, PERSISTENCE, SKILL

Louis Newman, who calls himself "an old peddler," says, "Three things are necessary in successful selling. These are Integrity, Persistence and Skill." He was highly successful so we can put stock in what he says.

We understand integrity to mean forthrightness and honesty — honest thinking and acting. Surely that is the most important trait for an Industrial Engineer to have. He can't get any place if people don't trust him.

Certainly he must be persistent. To succeed, he must overcome the "resistance to change" mentioned in most writings. He must keep at it—but with skill and integrity.

SELLING THE INTANGIBLE

Integrity and persistence are traits you add little to by reading articles. But maybe I can give you some suggestions that will improve your skill.

In selling ideas, you are under one handicap. Ideas are intangible. They are not like things you can see, feel, taste, hear or smell.

True, you can take your boss over to the A. B. Jones Company to show him what other folks are doing with the better idea you propose. But that isn't quite as conclusive as letting him hear a radio, drive a new car or watch a milling machine cut at high speed. After any of these tangible approaches, he can say, "I don't like it" or "We can't afford it." However generally, he cannot stop you in your tracks with his best defense, "Our business is different." This objection is the rock that can rip a hole in

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the bottom of your progressive idea and flood it with cold water.

RESISTANCE TO CHANGE

Don Copell maintains, "You can teach an old dog new tricks provided you know more than the dog" (1). According to Andrew Salter, "No one does what he should. He only does what he can, because that is what he is conditioned to do" (2). Perhaps a better explanation is one stated by Rudolph Flesch in his Art of Clear Thinking. He says, "Don't forget that everybody, including yourself, has only his own experiences to think with" (3).

From these statements, you can see that each idea is a "special sale." Each new idea may be wholly outside your buyer's experience. At the other extreme, it may exactly agree or be diametrically opposed to his own experiences.

Then too, you recognize that selling the first idea of a series is more difficult than the fifth or tenth one. Selling initially the idea of installing Job Evaluation, for example, may take you many months. But when you get over the hump, often you can more easily sell many ideas that relate to it.

EDUCATIONAL PROCESS

Primarily, you must recognize that selling your ideas is a process of "education." You must give the buyers of your ideas the "experience" as Flesch calls it. Otherwise, they cannot think along with you.

In this informative process, I believe that the critical adjustment is one of speed. Robert Rawls names it as the rate of "mental digestion." His pamphlet, "Time Out for Mental Digestion," stresses this part of selling. As one pointer, he writes, "To work more effectively with our associates, to get our ideas accepted, to have greater influence with people, we must allow them time out for mental digestion, and we must learn to curb our impatience when they refuse to be swept off their feet by our enthusiasm" (4).

GET THE PROOF

His term "enthusiasm" relates to Newmans "persistence." These terms suggest two more "angles" to watch. Right off you know that to sell your idea you need ammunition. In its simplest form, you call it "getting the proof." The lawyer calls it "preparing his case."

So your first step is to get the facts. You must show that your idea is "practical." It must pay for itself in your buyer's thinking. Often, it will cost time, effort or money. And your buyer must make a choice between disadvantages. As Bernard Lester puts it, "There is one fundamental urge that moves any enterprise to buy. It is to make money by avoiding loss" (5).

The loss Lester refers to is the excess of present costs over those you expect when your idea is applied. And I'm sure that you know very well how much better you can sell with dollar arguments.

Here is one illustration. Back in the depression, one company had more timestudy men than it knew what to do with. But the manager was smarter than many. Instead of laying them off, he assigned these men to make studies in prospective customer's plants, with permission of course. In many cases, the timestudy men could work out strong dollar reasons for buying the client's equipment.

RING THE BELL

You know, too, that the "savings" you can show cause differing reactions. These vary with your business conditions and with your buyer as a person. You get better results with some men by using charts and curves. Others are scared to death by graphics so you must use figures. With such men, you find that some visualize better with percents than amounts. So be sure to choose the right tools to make your sale.

For instance, one plant was a little slow in taking actions to correct some conditions brought out by timestudy. To get results, the Chief Industrial Engineer set the stage. He listed these potential savings in order of decreasing amounts and alongside he showed the accruals of totals involved as each was aded to those preceding. His figures were in monthly totals. His purpose was to emphasize one way to change the loss he expected on the next month's P & L statement into a profit. If the month's operations did show a loss, he planned to point to the corresponding amount on his summary of potential savings and say, "Here's one way to correct our loss."

AVOID MISTAKES

Obviously, you know you should not go off "half-cocked." Your idea should be economically feasible. That, by the way, is largely a question of multiplier—how many. That means your idea may be much more practical at another time.

However, my point here is to avoid mistakes. Of course, anyone who gets things done will make some mistakes. At the same time, we agree that "nothing succeeds like success." Thus your skill in selling ideas grows with your reputation for success. Naturally, you want to guard against making mistakes.

TALK TOO MUCH

In trying to minimize your mistakes, you prepare more carefully. This will increase your enthusiasm. It will give you more persistence. But both can cause you to work too hard to sell your idea.

The better approach is well brought out by Robert Rawls in "Silent Selling." In this booklet, he tells about a salesman named Gens who called on the grocery trade. "He would walk into a store, say "Good morning," and then wait—just wait, silently . . ." (6). And he goes on to describe how this salesman let his customers buy. Then he makes the point that since his experience with Silent Salesman Gens, he has become convinced that most salesmen "talk too much and too fast." Bernard Lester makes the same point with, "What buyers complain about most is constant chatter by salesmen" (7).

LISTEN FOR OBJECTIONS

In reverse English, these experts are telling us that we must listen more than we do. We must hear what our buyers object to. We must not try to smother them with words every time they point out some obstacles.

When we do get the proper opening we must not rush in all "het up" with our enthusiasm and give our listeners mental indigestion. We make bad matters worse because, usually, our ideas are bolstered with a mass of indigestible figures.

PROPER TIMING

Then too, you try to pick the proper time to make your sale. You think of timing when you hear someone ask, "How is the boss feeling today?" You may choose to present your idea on some other day. You may agree with those who say, "See him right after lunch." That's one way to look at timing.

But there is a type of schedule you may use to advantage. Perhaps this is a good method for major projects. It is what I call "Plant the seed and then water it." Your skill in using this method depends upon your experience. You must learn how long it takes your seed to grow up and bear fruit. When you have that timing in mind, you know when to plant your seed. Then you can water it at proper intervals. And it will bear fruit at the time you planned its adoption.

There is another twist to this method. You can pass along news items, articles and books containing statements of principle made by those who are supposed to know. I did that once very successfully to convince a controller that he should adopt a new idea in accounting. Incidentally, do not underestimate the halo effect of the printed word. Many take as gospel the statements they see in print.

ASK QUESTIONS

I have found it very helpful also to ask questions. One reason is to find out if you are being understood. Another is to learn what objections your buyer has. A third is to test the progress you are making in your sale. A fourth is to learn from your buyer's experiences.

Edward Goeppner brings out this latter reason as a remark he overheard a Negro janitor make, "Yeh, sho, thet's right, but it's the things you learn after you thinks you knows it all, that counts" (8).

I heard Dr. Lillian Gilbreth say almost the same thing several years ago. She told about one of her daughters announcing, "Mother, I know all the answers." To this Dr. Gilbreth replied, "That's nice But tell me dear, do you know all the questions?"

So be sure to ask lots of questions. You may discover that you had reasoned from a "false assumption to an erroneous conclusion." And if there are no flaws, at least you will find out what objections you must overcome.

DON'T BE HASTY

Now don't push too hard. Remember that old adage—"haste makes waste." Rawls states that some executives make it a rule that, "If you must have an immediate decision on any proposition, the answer is no" (9). So don't be too anxious to get going right away.

If you do, you may be inclined to compromise. About this form of solution M. P. Follett says, "But compromise sacrifices the integrity of the individual . . . " (10). "It usually means merely a postponement of the issue. The truth does not lie 'between' the two sides" (11).

There is a much better way out, especially for engineers — men with mental agility. Glenn Gardiner gives us one clue. He says, "There are three sides to a story — his side, your side and the right side." M. P. Follett brings this out in a different way. She says, "I find that we come to agreement not by adjustment but by invention, not by reconciling our ideas but by finding a new idea which is always something different from the addition of the previous ideas" (12).

These experts seem to say that we should utilize our buyers' objections to improve upon our proposals. We should use these to help us invent a better idea. Remember, there is always a better way.

GET PARTICIPATION

And the better way that includes his ideas will work better. As John Wilson explains, "Every man has two handles —a pride handle and a profit handle" (13). It is the "pride handle" you have grasped when you adopt his improvements upon your basic idea.

I'm thinking particularly of the many ideas Industrial Engineers install that must be carried out by someone else. You know from bitter experiences that these other folks can make your ideas fail to work time after time.

PROFIT HANDLE

To succeed, you must watch out for the "profit handle" as John Wilson names it. You must consider "intelligent selfishness," as James Lincoln identifies it, in all your sales efforts. How else can you expect to successfully talk someone into upsetting his comfortable routine, doing the extra work necessary to carry out your idea and then working back again into his desired smoothness of operation.

I stress this "profit handle" for a very good reason. Most of us are striving to "get ahead" — "make names for ourselves." There you have one reason at least why we are interested in learning how to sell our ideas. But let me caution you that it is vital to keep in mind who it is that is to "get ahead" with your idea.

WHO GETS CREDIT

Let me give you a test question. It is one of a series I use in training men. It reads, "A timestudy man should seek the credit for improvements he makes in methods." Now, most men answer this True. To be sure, many are younger men. Shall we say they are in a hurry to get ahead.

Nevertheless, won't you agree that the man who "seeks the credit" will run the grave risk of failing to sell his idea? What he should seek is the end product —the "practical" application of his idea. That involves not only letting the buyer add his improvements but also allowing him to take credit for putting the whole idea into successful operation.

HELP THEM GET IT

Maybe I have over simplified this subject. But from all I can gather, selling isn't very complex. Look how simple Frank Bettger makes it. His rule is, "Try to find out what people want, and then help them get it" (14).

His rule seems to summarize in one sentence much I have said. Surely it implies that you seek to perform some service for those you work with in the best interests of your company. It includes all I brought out about asking questions instead of doing all the talking. It covers all phases of trying to incorporate your buyer's suggestions even if you have to invent a whole new idea. And there isn't any question as to who gets the credit. Then may we agree, that the way to sell your ideas is to help other people get what they want.

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JOB SIMPLIFICATION

(Continued from Page 20)

This sample quiz has but seven questions. Where only 30 minutes are allowed for lunch, one or two questions might be used for each quiz. Where 60 minutes are allowed, as many as 10 questions might be included in each quiz. At the start of such a program a few simple questions might be better than many difficult questions.

The answers to these questions should be posted a day or two after the quiz so that even those who did not participate might learn what the answers are.

Here are a few suggestions for maximum and permanent good from such an educational endeavor:

1. Test your questions on a small group before "going to press." Ambiguity and other errors will save you a lot of headaches, if these are caught before the "boys" get them.

2. Be sure of your answers. Post your answers the following Monday (if QUNCH is played on Friday).

3. Be liberal with your lunch allowance. If the average luncheon check is 69c, give away $1.00 luncheon credits.

4. Don't attempt to monitor these quizes. Of course you don't have to encourage "cribbing." But the more interchanging of ideas you have the better will be your educational program. In other words this QUNCH game is both a measuring device and a thought accelerator.

5. Don't pressure anyone into participating in this noon-time game. It must be purely voluntary. Indeed, it would be well to consult with union officers ahead of time and tell them what you plan to do.

6. Throw in occasional baseball or other human-interest questions.

7. Answers should be short—unless interest builds up to the point where people ask for explanations.

8. If anyone furnishes proof of the validity of his answer compared with yours, grant him a free lunch.

9. Publish the answers and questions in your house organ, if you have one.

10. Give away a free lunch to everyone whose question is used in future quizzes.

"Collective Bargaining: Negotiations and Agreements"

by Selwyn H. Torff,

McGraw-Hill Book Company Inc,

New York, 1953, 323 pages, $5.50.

Mr. Torff's book is a broad discussion of the contemporary features of labor-management relations. He covers both sides of current issues with reasons for the positions taken. Specimen clauses are included to show representative solutions. The author also discusses the legal aspects of labor relations, the grievance procedure, and arbitration.

"Manufacturing Management,"

by Franklin G. Moore,

Richard D. Irwin, Inc.,

Homewood, Illinois, 1953, 832 pages, $8.00

Prof. Moore has written an excellent book thoroughly covering all important phases of manufacturing management. He shows the interrelationships of the various functions and discusses the influence of organization and employee relations on the different manufacturing activities. He also brings in the historical background and the economic and political factors important to today's industry.

Editorial Comment—

OR or IE?

By Dr. Robert N. Lehrer, Editor-in-Chief,

Professor of Industrial Engineering, Georgia Institute of Technology

Many of our readers have encouraged me to make a few comments about Operations Research and Industrial Engineering. Even though two excellent articles on Operations Research are included in this issue of the JOURNAL, a few extra comments are in order.

The Industrial Engineer is supposed to be an individual who sparks change, and strives for improvement. Why, then, does he himself resist change? A change that would result in a substantial improvement in his work ability. The specific "resistance to change" to which I refer is the Industrial Engineer's reluctance to adopt, adapt and intelligently use Operations Research as an Industrial Engineering tool. We find ourselves in somewhat the same predicament as the cobbler who never got around to making shoes for his family. Are we so engrossed in getting others to change and improve that we ourselves are in a rut?

Let's look at this problem of Operations Research and Industrial Engineering in a positive and creative way. There are logical reasons behind the development and success of Operations Research —and the thinking of many Industrial Engineers is one very significant factor. Operations Research is usually typified by the following characteristics:

1. Viewing problems in their overall setting.
2. Dealing with all parts of a problem, rather than just with a restricted segment.
3. The use of a team approach.
4. The use of expert knowledge in approaching a problem, defining it and developing a model of the problem.
5. The use of "participation" by interested parties in the solution of a problem.
6. The use of quantitative evaluation and measurement.
7. Direct relationship with "top management."
8. The use of experimentation.
9. Helping "top management" solve their own problems—by providing them with alternative courses of action, and knowledge of what is involved in each alternative.

Are these same views typical of the Industrial Engineering approach? They should be. The pioneers in our field intended us to view our problems in a broad manner, and I feel that they would take to Operations Research like a duck to water. In fact, it has been claimed that the pioneers in Industrial Engineering did originate Operations Research. Why then do many Industrial Engineers of the present resist Operations Research?

The Industrial Engineer's reaction to Operations Research has been mixed—perhaps tinged by envy, fear and frustration. Some have reacted violently—with claims that Operations Research and Industrial Engineering are one and the same. Others have been greatly impressed by the broadness of scope represented by the interdisciplinary research teams. Others, bless them, have been quick to make full use of the "new" tools to reinforce their old procedures without being much concerned about arguments of which is new and which is old. Still others fear that the demands of Operations Research make their training and experience obsolete.

Now for a closer look at a few reasons why the Industrial Engineer has reacted in his own particular way.

1. *There is a difference between the "scientist" and the "engineer."* The scientist has been mainly interested in knowledge for understanding, while the engineer has been preoccupied with solving practical problems. This has resulted in many situations where the scientist has lost touch with the practical aspects of his work, and the engineer has lost touch with the theoretical. The Operations Research approach requires heavy use of theoretical knowledge applied to practical situations. Many Industrial Engineers are ill-equipped to deal with their practical problems on a theoretical level. (It is interesting to note that most scientists are even less well equipped to deal with problems on the practical level.)
2. *Many Industrial Engineers like to "look at the world through a knot hole."* It's unfortunate, but true. Industrial Engineers do like to confine their problems to just one limited area of activity, even though the immediate problem area is greatly influenced by an overall "system." This thinking is responsible for some of the knottiest problems that have plagued the Industrial Engineer.
3. *Many Industrial Engineers lack skill and experience in research and experimentation.* Operations Research demands a good background in experimentation and research.
4. *Many Industrial Engineers lack facility with mathematics and statistics.* These quantitative tools are extremely important to the Industrial Engineer. They become even more important in experimental and research work. They are tools that allow quantitative treatment of data and the development of theoretical models of operational situations.
5. *Most Industrial Engineers lack a broad background in the human and life sciences.* Even though the Gilbreths did excellent pioneering in the integration of psychology (and other social sciences) into everyday Industrial Engineering, most Industrial Engineers have had little contact with other than a mechanistic approach to their work problems.
6. *Most Industrial Engineers tend to feel that their work is only concerned with production.* This has resulted in limiting the area of application of Industrial Engineering.
7. *Some Industrial Engineers are short on engineering and science.* These individuals will likely prefer to stay away from active use of Operations Research because they do not have adequate training to use it.
8. *Too many Industrial Engineers have management as a goal.* This has resulted in lack of interest in refined methods for being a better staff man. Operations Research is a staff tool.

Now for the constructive part. Why shouldn't we just stop and take stock—very carefully examine the overall problem and the possible courses of action. I strongly encourage you to do this. Read some of the basic material [1] that led to the development of Industrial Engineering. Also read more about Operations Research. In particular, read the two excellent articles in this issue of the JOURNAL. Then do some deep thinking, and reach your own decision. I know what it will be—*Operations Research should be in every Industrial Engineer's tool kit.* If we need additional training and knowledge—let's get it. The Industrial Engineer should retain his position as an Engineer *for* Management. Operations Research will help him do this more effectively.

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[1] I would suggest the following:

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THE QUALITY BOGEYMAN

(Continued from Page 7)

THE SPECIALIST

As is common to all specialized fields of activity, the Statistical Quality Control Specialist has engaged in the practice of Empire Building. In the last decade, he has usurped more and more authority while avoiding responsibility. Starting with simple inspection techniques, he widened his circle to include fact finding as to causes of deviation, Specification writing, Work Load Analysis, etc. The Control Chart has invaded the Controller's office and the President's graphs. All of these contributions to management control are valid and valuable. But they endanger the organizational set-up, particularly if these new and delicate tools are mishandled and manipulated. Like all Statistical techniques, the data may be manipulated for pre-planned ends. Therefore, management must be wise enough to train its key personnel in the proper interpretation of statistical data. As Hugo A. Weissbradt said, "Don't let the statistician run your show."[8] For example many offices now show a Control Chart of actual expenditures, with tolerance limits being the budgeted amounts. But the chart is not valid unless the process is "in control" to start with. A lot of ground work must be done before a chart is drawn. This is not the province of the Statistical Quality Control Specialist.

The Specialist, of course, has a well-earned place in the Quality scheme. For example, a potent source of inspection rejections is the lack of proper coordination between prime and sub-contractor. Usually, the prime contractor's engineers design the final assembly and then farm out the sub-assemblies and components. Their engineers are not trained or even aware of the manifold special requirements of the sub-contractor. They specify machine tolerances for spun metal work. They require precisions instrument accuracy for glass bottles. They over-design and under-simplify. Thus they limit both their sources and their own production.

Only a little effort would be required to call in the sub-contractor, a painting specialist, a production man, a metallurgist, and integrate the diverse viewpoints of these specialists. They could design as simple and practical a part as American ingenuity could devise. Months of delay could be avoided in this way. Inspection controls could be based on the widest tolerances and specifications that were practical. In this approach the design engineer is a manager, using the Specialist's knowledge to good advantage. He should not consider it a sign of weakness to display lack of knowledge in specialized fields. What top executive really believes he knows all?

CONCLUSIONS

A true understanding of good inspection practice lies in a re-examination of the meaning of AOQL (average outgoing quality level) and of the difference between a major and a minor defect. I agree that every factory should strive for commercial perfection. Practically, it is wasteful and stupid to provide better quality than that called for by the customer. If he will accept 3 percent bad work, set that sight. If he demands 100 percent good work, he is asking for the impossible. Tell him so.

There are degrees of good or bad. If a part has a scratch on it but serves no aesthetic purpose it should not be rejected. The concept of quality being as good as is necessary for use and not better is recognized by most industrial engineers. In practice they give it lip service only. Too often the limitations of efficient commercial practice have been ignored. "Application of Conventional plans to a large variety of short runs creates a volume of records out of proportion to the economic gain these plans can give."[9]

Mass production itself is feasible only under rather rigid control of quality. But to expect perfection in minor matters is to go beyond the limit of the practical. As long ago as Feb. 27, 1948, the Munitions Board issued to the Munitions Board Material Inspection Committee Directive No. 1—Subject: Development of Uniform Material Inspection Standards. In this directive, among other things, the Committee was to help establish the most effective and economical basis for the performance of inspection functions. Here was implicit recognition that the problem existed. Since then it has grown knottier. MIL Standard 105 poses vast problems for the small and medium sized manufacturers. As defense components increase in complexity, it seems to me that we must end up with automatic machine sampling inspection or with chaos.

It would be a great pity if the Statistical Technique is circumscribed or abandoned because of current excesses. Its contributions have been many. They are but few compared with its possibilities. Let's not undermine the structure by causing waste and delay in the name of quality. We should move confidently forward to make full use of Statistical Quality Control as one factor in a well-integrated management structure.

[8] A.M.A. Prod. Ser. No. 181, "Quality Control in Action," 1949, page 8.

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Richard D. Irwin, Inc.,
Homewood, Illinois, 1953, 344 pages, $6.65

To those who want a comprehensive one-volume history of the scientific management movement, Filipetti's book is highly recommended. He outlines the major contributions of the pioneers, Taylor, Gantt, Gilbreth and others to the profession which has since become industrial engineering. In his eminently readable style, the author covers later developments in scientific management which have influenced management, labor and industry both here and abroad. The revised edition provides coverage of events since the publication of the first edition in 1946.

OPERATIONS RESEARCH

(Continued from Page 13)

Factory Maintenance and Management, October 1953. (Reprints from Mr. Melden, 330 W. 42nd St., N .Y. C.)

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The Role of Plant Layout and Design

By Dr. Eugene Richman

Assistant Professor of Industrial Engineering, Ohio State University

The terms Plant Layout and Plant Design are often used interchangeably. Plant Design is used here in the broad sense to mean the overall design of the industrial enterprise, encompassing the long and short term planning of top management. This includes the design of the organization structure, the financial structure, the manufacturing facilities, the sales and distribution program and the anticipated growth pattern. Plant Layout, however, is restricted to mean only the selection and arrangement of physical facilities so as to accomplish as efficiently as possible the objectives of Plant Design.

With this interpretation of terminology, what then are the objectives of Plant Design? Are these objectives multiple? Are they mutually exclusive? Are they compatible?

The following is a listing of some of the major objectives of Plant Design:

1. To successfully establish a going organism for the production, distribution and sale of some useful product or service.
2. To perpetuate this organism on a sound basis so as to offer continuing service to present and future consumers of its product or service.
3. To conduct all operations at as high an efficiency as possible.
4. To provide desirable employment to its employees.
5. To offer a satisfactory return to its owners.
6. To be an asset to its community both locally and nationally.

These objectives are important in varying degrees to the owners and employees of the concern, to the consumers of its goods or services and to the government. It is obvious that these objectives are multiple, that they are not all mutually exclusive and that there is some incompatibility.

Let us now re-examine each of these major objectives in terms of their sub-objectives and inquire into the relationship of the Plant Layout function to these Plant Design objectives. The first objective, "To successfully establish a going organism for the production, distribution and sale of some useful product or service," depends a great deal upon pre-planning and forecasting procedures. The product will have to be designed and market research initiated. The financial and organizational structure, the quality, pricing, procurement, sales, service and distribution policies will have to be determined. Also required is the initial financing, the rental or construction of suitable physical plant for housing the production and service facilities, the hiring of personnel, the attainment of initial inventory and the installation of machinery and equipment.

The Plant Layout, then, must be completed before Plant Design objective number one can be met. The layout, in order to be effective, must take into account many of the top management plans and policies. Certainly, this points out the need for close contact between the individual charged with the responsibility of Plant Layout and top management.

The second Plant Design objective, "To perpetuate the organism on a sound basis," is one which emphasizes the dynamism of Plant Design. To be a hardy organism, the enterprise must be one which can withstand difficult times. It must be able to survive in times of lowered production. It must be able to meet or be adapted for expanded production. It must be able to manufacture a product which may periodically call for drastic design changes, or it may have to produce a different line altogether either due to a change in consumer demand or to meet a military requirement. This objective poses one of the most difficult of Plant Design problems. That problem is to meet today's needs and still be able to change with changing times. Although there is considerable difference from one industry to another, the best way to meet today's needs is often by rigid design, leaning towards line production techniques, specialized equipment, and low skilled workers. The best way to be adaptive, however, might be through the design of a more departmentalized plant, with a high degree of flexibility, general purpose machines and highly skilled workers. This fundamental requirement of perpetuity of the enterprise thus constitutes in itself a conflict. The answer is compromise, but, compromise to what extent? Certainly, the greater the predictive ability of the industry to forecast future conditions, the easier it will be for the Plant Layout department to arrive at the most suitable compromise; one that will minimize the costs over the years rather than a layout which makes for lowered costs for a few years and increased costs later on or vice versa. In fact, a sub-objective might be to arrive at a cost policy in terms of time. Again, the ability of the Plant Layout department to meet the needs of the second design objective will depend greatly upon the extent to which the Layout department is informed about these objectives.

Not only is the initial layout of important is the in-built capacity of the two, but also, perhaps even more important, is the inbuilt capacity of the layout department for layout modification. A good initial layout may make modification easier but it can never be expected to make it unnecessary. Thus, the need for a continuing liaison between top management and Plant Layout.

The third Plant Design objective, "To conduct all operations at as high an efficiency as possible," to a certain extent is implied in the second objective. However, there is a significant reason for stating this as a separate objective. The second objective implies making the most efficient layout, while the third objective is to utilize as efficiently as possible whichever layout that is chosen and to do so on a continuing basis as the layout is modified. While it is not the function of the layout department to see that the human and mechanical means of production are utilized fully, it is necessary for the layout people to know what full capacity is, what the percentage of utilization probability is likely to be for workers and machines, for departments and for the plant itself. This knowledge, which so often is lacking, is fundamental to proper layout planning and modification. This design objective is especially important to the Layout Department. It indicates how great an interdependence there should be between the Layout personnel and other Industrial Engineering areas.

"To provide desirable employment to its employees"; this objective is one which has been getting a great deal of recognition of late. It is becoming an accepted management responsibility to make the place of work not just conducive to worker acceptance, but to provide worker satisfaction, to give the worker a feeling of pride in association and a feeling of belonging. The layout department which must plan the physical surroundings of the workers must have the most up-to-date knowledge of the workers' physiological, psychological and sociological requirements. They must know such things as what colors will help provide a maximum stimulus for work, a pleasing atmosphere, and maximum safety. They must provide adequate employee services, such as cafeterias, first aid stations and recreational facilities. They must be able to provide a safe, comfortable and pleasing environment for the worker. This objective of employee satisfaction is an end in itself, but it also benefits others. Efficiency increases with morale. Costs go down and quality goes up with increased efficiency. The owners, consumers and the government all stand to benefit from the successful attainment of Plant Design objective number four.

Plant Design objective five, "To offer a satisfactory return to its owners," is a most important objective. For sound financing of an enterprise, a large portion of its capital must come from the stockholders. This cannot be done in a free enterprise system without a suitable return for the investors. The ex-

tent to which this can be done depends on how well all of the other objectives are met. A company will be in a better position to offer a satisfactory return to its investors if the enterprise was well conceived to begin with; if it had a sound financial basis; if it offered a desirable product or service; if it was organized in such a manner as to adapt to changing external or internal factors; if it is continuously operated in an efficient manner; if its employees are properly motivated and compensated; and if it is not overly burdened with government restrictions, regulations and taxations. Plant layout does not contribute directly to this design objective, but it has a definite effect to the degree that it is concerned with the other objectives.

The final objective, "To be an asset to its community both locally and nationally," is one which clearly stems from the mutual privileges and responsibilities that accrue to both the enterprise and the community due to the very actuality of their coexistence. Again, this is a vital Plant Design objective but one which Plant Layout can serve only indirectly through its contributions to other design objectives. Both the local and national community benefits when a worthwhile product or service is made available to it. The community benefits when its members are gainfully employed. The community benefits when taxes can be levied on a company's profits. The community benefits when a company's products can be made available for national defense purposes.

The degree to which the community, the owners, the consumers and the employees benefit from the profitable operation of a company is an important and controversial matter. It is one which is of great interest and concern to those who undertake Plant Design. However, this question is not within the realm of this report. Good Plant Layout can contribute to a greater reservoir of both monetary and non-financial reward for the benefit of all who are to share in the fruits of an industrial enterprise.

In summary, the four basic ways in which the Plant Layout department can best serve to help accomplish the objectives of Plant Design seem to be as follows:

1. To be well grounded in the fundamentals of Plant Layout and to keep up to date on sources of information and on layout techniques. Adequate information should be maintained about men and machinery space allocations for production and office facilities, about machinery and equipment functions, times and limitations, about building structural requirements, about power and maintenance requirements and about service requirements such as cafeterias, first aid centers, recreation areas, comfort provisions and the like.
2. The layout department should strive to maintain close ties with top management, to facilitate communications with top management and to keep layout objectives current with Plant Design objectives.
3. The layout department should strive to maintain close ties with related industrial engineering departments and to facilitate communications and coordinated activities with such departments as Methods and Standards, Production and Tool Engineering, Production, Cost and Quality Control, Industrial Relations, Market Research and Sales Engineering.
4. Plant Layout should strive to engage in or cooperate with research efforts aimed at getting a more fundamental knowledge about working with men, money, materials and machines. There is a need for greater tie-ins with psychologists and sociologists. There is a need for greater predictive ability about markets, production requirements and labor and machine capacities.

In these ways the plant layout department can serve to fulfill its role in the industrial enterprise.

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Guaranteed Circulation of 4,000 copies

Published Six Times per year: January, March, May, July, September, November

Send all copy:

JOURNAL OF INDUSTRIAL ENGINEERS
Editorial & Publication Office
225 North Avenue, N.W.
Atlanta, Georgia